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NOGRAPHS ON MINERAL RESOURCES  
WITH SPECIAL REFERENCE TO THE  
BRITISH EMPIRE

PREPARED UNDER THE DIRECTION OF THE  
MINERAL RESOURCES COMMITTEE OF THE  
IMPERIAL INSTITUTE, WITH THE ASSISTANCE  
OF THE SCIENTIFIC AND TECHNICAL STAFF

# MANGANESE ORES

BY

A. H. CURTIS, B.A. (LOND.), F.G.S.

ASSOC. M. INST. C.E., M. INST. M.M.

(Specially attached during the War to the Staff of the Imperial Institute)

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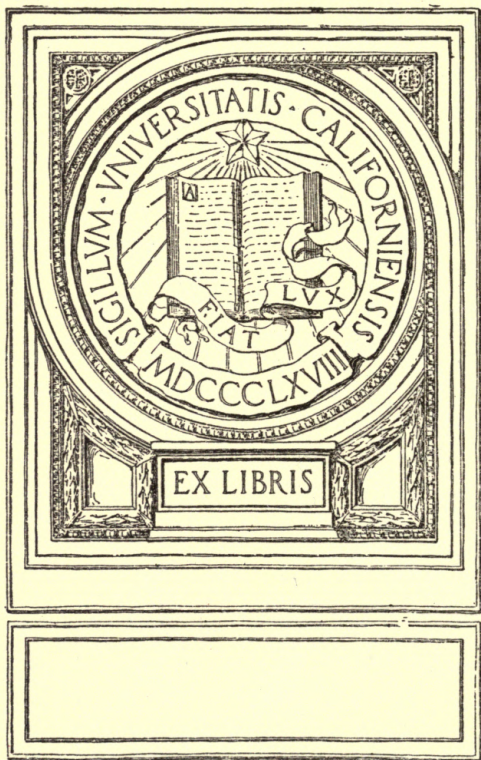


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**WITH SPECIAL REFERENCE TO THE BRITISH EMPIRE**

Prepared under the direction of the Mineral  
Resources Committee of the Imperial Institute

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## PREFACE

THE Mineral Resources Committee of the Imperial Institute has arranged to issue this series of Monographs on Mineral Resources in amplification and extension of those which have appeared in the *Bulletin of the Imperial Institute* during the past fifteen years.

The Monographs are prepared either by members of the Scientific and Technical Staff of the Imperial Institute, or by external contributors, to whom have been available the statistics and other special information relating to mineral resources collected and arranged at the Imperial Institute.

The object of these Monographs is to give a general account of the occurrences and commercial utilisation of the more important minerals particularly in the British Empire. No attempt has been made to give details of mining or metallurgical processes.

HARCOURT,  
*Chairman, Mineral  
Resources Committee.*

*June 1919.*



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# MANGANESE ORES

## CHAPTER I

### MANGANESE ORES : THEIR OCCURRENCE, CHARACTER AND USES

THE importance of manganese in the manufacture of iron and steel is continuously increasing; stricter demands as regards the chemical and physical qualities of manganese ores are being made, not only by metallurgists but also by those using such minerals in chemical industries; the necessity for an increased production of high-grade manganese ore has become urgent, and new sources of supply are required. The effect of the war has been to increase the demand for iron-manganese alloys (more particularly for ferro-manganese, the consumption of which has grown largely in recent years), and at the same time to cut off or seriously curtail supplies of the ores necessary for their production.

Ores of the metal are widely distributed, but there are only a few countries in which important deposits are known. Of these the principal are Russia (Caucasus), Southern and Central India, and East-Central Brazil, which have hitherto furnished practically the whole of the world's supplies of manganese-ore, properly so called. Among other countries which have already produced manganese-ore, or which are known to contain deposits of some prospective commercial value, the following may be mentioned: Austria-Hungary, France, Germany, Greece, Italy, Spain; West Africa (Gold Coast), Egypt (Sinai Peninsula); Canada, the United States of America, Mexico, Nicaragua, Costa Rica, Colombia, Cuba, Chile; Queensland.

The leading producer of manganese ore before the war was Russia, followed closely by India, Brazil coming third. Owing to the closing of the Dardanelles and of the Russo-

German frontier, and to the disturbed conditions still prevailing, the Russian producers have temporarily lost their foreign markets. Prior to the war, Germany was the largest buyer of the high-grade Caucasian ore, the United Kingdom, Belgium and the United States coming next, in order of importance. The chief sufferer among the steel-making countries has been the United States, where the situation of the industry has admittedly been serious, owing to the cutting-off of Russian supplies and the deficiency in shipments from India. The shortage arising from these conditions was more particularly felt in 1914 and 1915, when the imports of manganese-ore from Brazil, although considerably increased, were not sufficient to meet the demands of the United States. In 1916, however, the export of ore from Brazil was increased nearly two-fold over that of 1914; and, as most of this was absorbed by the United States, it is to be inferred that the situation in that country has been considerably relieved, although prices there are still much higher than before the war. Not only is the United States dependent upon foreign countries for its supplies of manganese ore proper, the domestic production of which is even at the present time almost negligible, having regard to the enormous requirements, but large quantities of iron manganese alloys had to be imported in pre-war times, chiefly from the United Kingdom, and to a much smaller extent from Germany and other European countries, in order to supplement the domestic production of such alloys. The war has naturally had an adverse effect on the export of ferro-manganese from the United Kingdom.

But for the deposits, in New Jersey, of the complex mineral known as franklinite (primarily a zinc ore from which manganese is obtained as a by-product), and of certain manganeseiferous iron ores of which the annual production has for some years averaged well over 500,000 tons (the Lake Superior region furnishing considerably over 90 per cent. of this output), the steel-making industry of the United States would be almost entirely dependent on extraneous sources of manganese.

The Brazilian manganese ores, for which the United States has hitherto been the best customer, are estimated to be



sufficient to supply the world's requirements for several centuries; but the large development of the manganese industry in that country has been greatly obstructed by the distance of the deposits from the coast, difficulties and cost of transport, etc. During the three years immediately preceding the war, the exports of Brazilian manganese-ore fell, and the present revived state of the industry, due to the accidental requirements of the United States, may or may not be a criterion for peace times in the future. However, as the figures for and since 1916 show, the Brazilian exports are capable of important increase in the event of a permanent improvement in prices. Russia also should be able to increase her output. It must therefore be expected that India will have to face strong competition with both Brazil and Russia when industrial conditions become more settled.

The Russian (Caucasus) ore contains from 52 to 56 per cent. of manganese, the Brazilian from 49 to 54 per cent., averaging about 53 per cent., and the Indian from about 45 to 55 per cent., averaging possibly from 50 to 52 per cent. In general, shipments to Europe vary from as low as 37 per cent. to as high as 55 per cent. of manganese. Cargoes to Great Britain (which include Spanish manganimiferous iron ore and small tonnages of ore from other minor sources of supply, in addition to the main supplies from the three chief producing countries) average probably nearly 50 per cent. of manganese. British and other European manufacturers of ferro-manganese find it advantageous to draw their ores from various sources in order to obtain certain mixtures.

The British-Indian production of manganese ores ranked, as regards quantity, second only to that of Russia during the years immediately preceding the war. India, indeed, occupied the position of leading producer for the four years 1908-11, notwithstanding the fact that production of manganese-ore began in Russia so long ago as 1879, while the Indian industry was started fourteen years later and the rich deposits in the Central Provinces were not discovered until 1899. This remarkable result is attributable in large measure to superior organisation, stricter control, more suitable mining methods, lower railway freights and more adequate rolling-stock than

have hitherto characterized manganese ore production in Southern Russia.

But for the handicaps already mentioned, Brazil might several years ago have become a more serious competitor with British India in European manganese markets; and, indeed, if there should be any further settled improvement in prices, the revival in the Brazilian industry, due to the requirements of the United States, may well prove to be more than a passing phase of its history.

The production of manganese ore in the United Kingdom, which has only in one year exceeded 20,000 tons, is now almost negligible; and, although the deposits are not yet exhausted, there is little or no prospect of our domestic production ever becoming important, even if prices should considerably advance. Not only are the deposits small, but the ore which they contain is of low grade.

Among the most promising discoveries of manganiferous minerals in quite recent years are those which have been made in the west-central portion of the Sinai Peninsula. The existence of manganiferous areas in this part of Egypt was discovered in 1898, but it was not until 1913 that any deposits had been demonstrated to be of economic importance. Preparations for the exploitation of certain areas were commenced in that year, and railway communication with the Gulf of Suez has since been established. The deposits are of considerable thickness, and extend over large areas; but they appear to consist chiefly of manganiferous iron ore; and it would seem premature to hazard an estimate of the average composition of the ore they are likely to yield.

What appears to be an important deposit of high-grade manganese ore was discovered in 1915 about 75 miles west of Port Augusta, in South Australia. Should the results of the early exploratory work be confirmed by mining on a commercial scale, the present limited requirements of the whole Australian market might easily be met from this one source of supply, and there should be a substantial surplus for export.

A promising discovery of high-grade manganese ore was made in 1914 at Dagwin, in the Wassaw district of the Gold Coast Colony, West Africa, and the deposit, which is situated

quite close to the Government railway from the port of Sekondi, some thirty miles distant, is now being exploited. Particulars of this deposit are given later.

The Canadian manganese ore industry has been checked in development by the insignificant domestic demand for the high-grade pyrolusite, of which the known deposits largely consist, the annual consumption in the home chemical industries being only about 20 tons ; while the absence of good transport facilities has rendered it more profitable to import ore of lower grade than to put high-grade Canadian ore on the market.

Deposits of low-grade manganese ore are stated to occur on the south side of Conception Bay and elsewhere in Newfoundland.

While it is permissible to suggest that prospecting in other parts of the British Empire may lead to important discoveries of manganese ore, it must be admitted that, in the majority of instances where promising deposits in our Dominions and Colonies have been reported, these have proved to be of only small economic importance. It is nevertheless hoped that the information contained in this monograph may be of practical value to companies concerned with the exploration of mineral concessions in British territory, to individual prospectors, and to users of manganese-ore throughout the Empire, especially manufacturers of iron and steel.

*World's Production of Manganiferous Iron Ores and  
Manganiferous Zinc Ores (1909-1915)*

(Long Tons)

Year.	Manganiferous Iron-Ore.			United States. <sup>3</sup>	
	Germany. <sup>1, 2</sup>	Greece. <sup>3</sup>	Italy.	Manganiferous Iron-Ore.	Manganiferous Zinc-Ore.
1909 . .	75,937	54,043	25,415	843,689	141,264
1910 . .	79,264	49,211	25,287	619,735	137,173
1911 . .	85,894	25,664	6,378	522,357	109,296
1912 . .	90,988	14,081	Nil	868,501	104,670
1913 . .	325,481	2	2	672,146	102,239
1914 . .	2	2	2	445,827	100,198
1915 . .	2	2	2	801,290	159,318

<sup>1</sup> Includes a certain amount of true manganese ore. <sup>2</sup> Figures not available.

<sup>3</sup> Statistics from compilations by *U.S. Geol. Surv. and The Mineral Industry*, excepting those for Greece and Italy, which are as in *Rec. Geol. Surv. Ind.*, 46 (1915). In 1916, the production of manganiferous iron ore in the United States was 548,803 tons, that for 1917 being 1,050,000 tons.



*Production of Manganese-Ore in Principal Producing Countries (1909-1916)*  
(Long Tons)

Year.	North America.		South America.	Europe.								Asia.		Africa.	Australasia.			
	Canada.	United States. <sup>2</sup>	Brazil. <sup>3</sup>	Austria-Hungary. <sup>5</sup>	Belgium.	France.	Greece.	Italy.	Russia.	Spain.	Sweden.	Turkey.	United Kingdom.	India.	Japan.	Union of South Africa.	Australia.	New Zealand.
1909	Nil	1,544	236,982	35,096	6,171	9,252	5,289	4,626	726,978	7,703	5,189	7,459 <sup>10</sup>	2,768	644,660	8,708	—	603	6
1910	Nil	2,258	249,954	32,445	Nil	7,874	40	4,134	719,907	8,471	5,719	12,008 <sup>11</sup>	5,467	800,907	11,121	51 <sup>12</sup>	815	5
1911	5	2,457	171,172	33,769	"	5,906	721	3,460	572,028 <sup>8</sup>	5,519	5,347	—	4,987	670,290	9,615	116 <sup>13</sup>	1,151	Nil
1912	67	1,664	152,431	27,514	"	5,488	7,595	2,599	911,742 <sup>6</sup>	17,126	5,082	—	4,170	633,080	11,862	—	328	—
1913	Nil	4,048	120,330 <sup>4</sup>	39,612	"	7,610	547 <sup>7</sup>	1,622	1,289,370	21,254	3,938	—	5,393	815,047	2,276	—	27	—
1914	25	2,635	180,680	6	6	6	549 <sup>7</sup>	1,622	725,450	6	3,584	—	3,437	682,898	16,802	—	26	—
1915	179	9,709	284,109	6	6	6	401	12,375	50,000 <sup>9</sup>	14,098	7,485	—	4,640	450,416	25,454	—	1,260	—
1916	874	26,966	495,179	6	6	6	6	6	150,000 <sup>9</sup>	6,705 <sup>3</sup>	6	—	5,140	645,204	6	4,274 <sup>14</sup>	2,652 <sup>15</sup>	—
1917	180 <sup>1</sup>	122,275 <sup>9</sup>	524,434	6	6	6	6	6	57,404	—	6	—	9,942 <sup>16</sup>	590,813	6	30,275 <sup>14</sup>	6	—

<sup>1</sup> Subject to revision.

<sup>2</sup> Not including manganiferous iron-ore.

<sup>3</sup> Exports.

<sup>4</sup> D. F. Hewett (Min. Res. U.S., 1914) gives 180,738 long tons.

<sup>5</sup> Includes Bosnia and Herzegovina.

<sup>6</sup> Statistics not available.

<sup>7</sup> Sales.

<sup>8</sup> Exported from Batoum and Poti.

<sup>9</sup> Estimated.

<sup>10</sup> Year ended March 1909.

<sup>11</sup> Exported from Stratonii.

<sup>12</sup> Natal only. Quantity produced in Cape Province not stated, but exports valued at £1,622.

<sup>13</sup> Cape Province (exports).

<sup>14</sup> Gold Coast exports.

<sup>15</sup> Not including South Australia, where manganese-ore valued at £2,700 was produced, the tonnage not being recorded in the Reviews of Mining Operations in the State for 1916.

<sup>16</sup> Home Office Statistics. For Ministry of Munition figures, see p. 24.

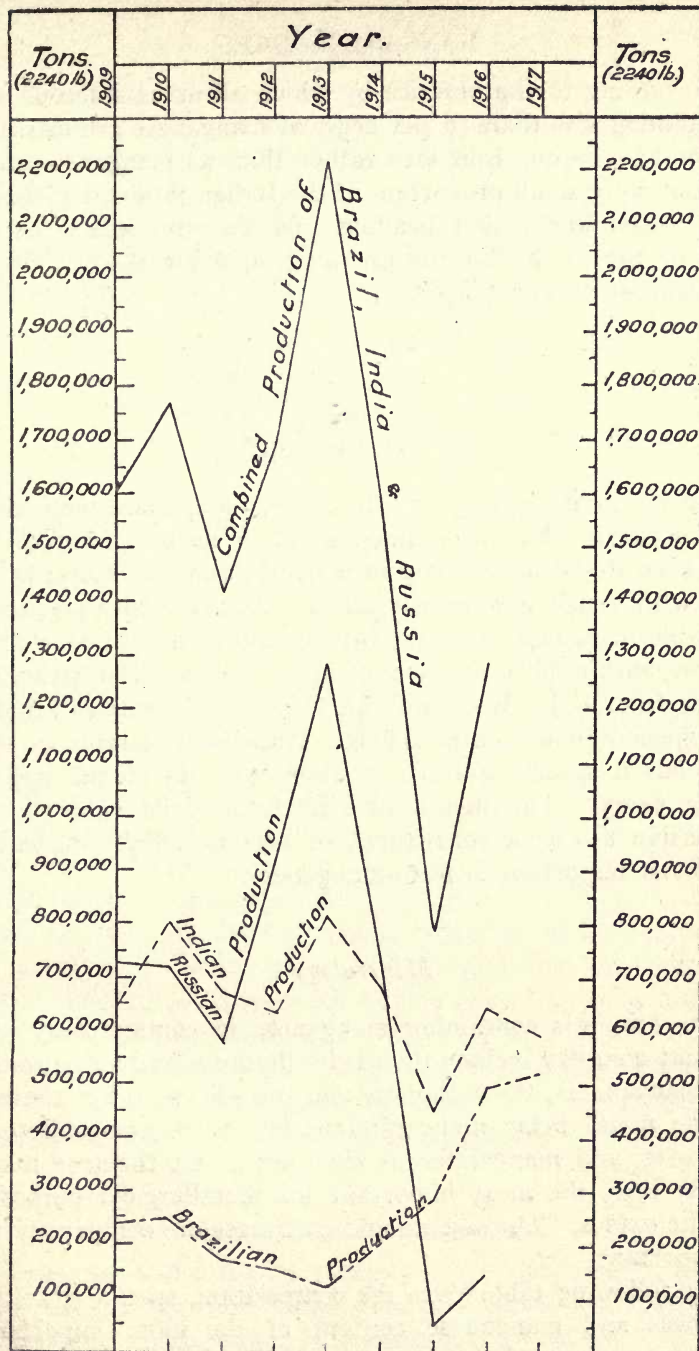


DIAGRAM I.—OUTPUT OF MANGANESE ORE BY THE THREE CHIEF PRODUCING COUNTRIES (INDIA, RUSSIA AND BRAZIL) 1909-1917.

According to the practice by which all manganiferous ores containing less than 40 per cent. of manganese are classified as manganiferous iron ores rather than as manganese ore, a certain very small proportion of the Indian production should be classed under that heading. Of the ores mined in the United States, by far the greater proportion is very low in manganese (1 to 8 per cent.).

### MANGANESE ORES

Owing to its strong affinity for oxygen, manganese does not occur in the uncombined state in nature, although it has been found as an alloy in meteoric iron, the metal being one with which it is closely allied. As artificially prepared, metallic manganese is hard, brittle, and of a light steel-grey colour, with reddish lustre, showing a fine granular structure when fractured. It cannot be forged. It oxidizes rapidly on exposure to moist atmosphere. It melts at about  $1,245^{\circ}\text{C.}$ , and has a specific gravity of about 7.5, its atomic weight being 54.93. The metal owes its commercial value to its extensive use as a constituent of certain alloys, of which the most important is ferro-manganese.

### *Mineralogy*

The minerals containing manganese in commercially important quantity include the oxides (hydrous and anhydrous), the manganates, the carbonate and the silicate, other sources of the metal being manganiferous iron ores, manganiferous zinc ores, and manganiferous silver ores. Of the true manganese ores, the most important for metallurgical purposes are the oxides. The silicate and carbonate are comparatively unimportant.

The following table gives the composition, specific gravity, hardness and manganese content of the more important manganese ores:



Mineral.	Composition.	Specific gravity.	Hardness.	Percent age of Manganese.
<i>Oxides :</i>				
Pyrolusite .	MnO <sub>2</sub>	4.73-4.86	2-2.5	63
Braunite <sup>1</sup> .	Mn <sub>2</sub> O <sub>3</sub> + $x$ SiO <sub>2</sub>	4.75-4.8	6-6.5	64.3
Manganite	Mn <sub>2</sub> O <sub>3</sub> . H <sub>2</sub> O	4.2-4.4	4	62.5
Hausmannite	Mn <sub>3</sub> O <sub>4</sub>	4.7-4.86	5-5.5	72
Franklinite <sup>2</sup>	(FeZnMn) O . (FeMn) <sub>2</sub> O <sub>3</sub>	5.07-5.22	5.5-6.5	10-19
<i>Manganates :</i>				
Psilomelane .	MnO <sub>2</sub> + MnO + BaO + K <sub>2</sub> O + $x$ H <sub>2</sub> O	3.7-4.7	5-6	45-60
Wad . . .	Impure earthy mixture of hydrous manganese oxides passing into psilomelane	3.0-4.3	1-6	5-50
<i>Carbonate :</i>				
Rhodochrosite (Dialogite)	MnCO <sub>3</sub>	3.45-3.6	3.5-4.5	47.8
<i>Metasilicate :</i>				
Rhodonite .	MnSiO <sub>3</sub>	3.4-3.68	5.5-6.5	41.86

<sup>1</sup> *Braunite*.—From 8 to 10 per cent. of silica is sometimes contained in this sesquioxide of manganese; and is supposed by some to be chemically combined, in which case it may be regarded as a silicate of manganese.

<sup>2</sup> *Franklinite* is more strictly a manganiferous zinc ore.

According to G. L. Barnebey [1], while various methods for the determination of the manganese contained in pyrolusite, the principal manganese ore, have been studied by chemists, the methods in use for determination of "available" oxygen have received but little attention. Results for the percentage of manganese dioxide obtained by responsible chemists have given differences of as much as five per cent. on a carefully prepared sample, while differences of one or two per cent. are quite common. The paper by Barnebey contains the results of a detailed study of the causes of such discrepancies, and recommends two accurate methods for the analysis of oxidized manganese ores.

### MANGANIFEROUS IRON ORES

These contain a highly variable proportion of iron, usually exceeding 40 per cent. Such ores are mixtures of manganese oxides and iron oxides. It is customary to divide them into, (1) iron ores, (2) manganiferous iron ores, and (3) manganese

ores. Manganese is not usually paid for when an iron ore contains less than 5 per cent. Mn, so that such an ore containing less than that percentage may be included in class (1). Ores with not less than 40 per cent. of manganese are included in class (3). Below that limit, down to 5 per cent. of manganese, the ore is called a manganiferous iron ore, although it may contain much more manganese than iron. In order to avoid this difficulty, the following classification, applicable to all ores containing over 50 per cent. Mn + Fe, has been proposed [2] :

Class.	Mn per cent.	Fe per cent.
Manganese ores . . .	40-63	0-10
Ferruginous manganese ores .	25-50	10-30
Manganiferous iron ores . .	5-30	30-65
Iron ores . . . . .	0-5	45-70

*Pyrolusite*.—This peroxide, otherwise known as “black manganese,” crystallizes in the orthorhombic system, but the common form is a pseudomorph after manganite. The ore usually occurs massive or reniform, sometimes with a fibrous and radiate structure. It is often impure, containing iron, silica, lime, baryta, etc., with in many cases a little water. It is very soft, soiling the fingers. The mineral varies in colour from black to steel-grey and bluish-grey, and has a black streak. The bulk of the Russian (Caucasian) ore consists of pyrolusite.

*Braunite*.—This is an anhydrous sesquioxide of manganese, invariably associated with silica, whether mechanically mixed or chemically combined, the proportion of silica being sometimes as high as 8 or 10 per cent. It crystallizes in the tetragonal system, occurring in pyramids resembling regular octahedra, and also occurs massive.

*Manganite*.—This is a hydrous sesquioxide of manganese, otherwise known as “grey manganese ore.” It crystallizes in the orthorhombic system, the crystals being often of many times greater length than breadth, assuming a needle-like form. Its colour is steel-grey to iron-black, with sub-metallic

lustre, and its streak reddish-brown to nearly black. When pure, it contains 10.23 per cent. of water.

*Hausmannite*.—This is a mineral, very low in oxygen, crystallizing in tetragonal prisms, frequently twinned, also occurring massive and granular. Its colour is brownish-black; streak chestnut-brown.

*Psilomelane*.—This is a hydrous oxide of manganese, with or without varying amounts of baryta and potash. It is amorphous, the common form being rounded or botryoidal masses, usually with a smooth surface. It also occurs reniform and stalactitic. Its colour is iron-black, passing into dark steel-grey and sometimes, as in India, to an almost bluish-grey. Its streak is often brownish-black, owing to a proportion of the lower oxide being present, and shining; but in India, quite as commonly, it is black. *Psilomelane* is the most abundant of all the manganese ores found in India, constituting with *braunite* probably at least 90 per cent. of the ore exported.

*Wad*, or “*bog manganese*.”—In general, this cannot be considered as a true manganese-ore. It is a mixture of oxides of manganese ( $\text{MnO}_2$  and  $\text{MnO}$ ), with oxides of cobalt and copper, and sometimes of silver, these giving certain varieties a special value. Iron is also present, and the ore contains from 10 to 20 per cent. of water. It results from the decomposition of other manganese minerals, and occurs generally in damp, low-lying places. It is amorphous, earthy, soft and friable, and resembles *psilomelane* except as regards hardness. It is not so valuable as *pyrolusite* or *psilomelane*, but is sometimes used in the manufacture of chlorine and of the pigment umber, and possesses value when used as a flux.

*Rhodochrosite*, or *Dialogite*.—This is a carbonate of manganese, often with carbonates of iron, calcium and magnesium in varying quantities. Rhombohedral crystals occur rarely, the mineral being more commonly found massive, globular, botryoidal, or encrusting. Its colour is white, pink, brownish, or yellowish-grey, with a rather pearly lustre; streak white. The ore has been extensively mined in the French Pyrenees (Las Cabesses, etc.) and a few other localities. It must be roasted for removal of carbon dioxide before being charged



into smelting furnaces ; and as, in the case of a comparatively pure ore, this leaves an oxidized product considerably higher in metallic manganese than much of the oxidized ores exported, it would be advantageous, having regard to freight charges, that carbonate ore should be roasted before shipment, where suitable fuel is cheaply available.

*Rhodonite*.—This is a pyroxene belonging to the triclinic system. It occurs either in crystals or massive, or as imbedded grains. The manganese may be in part replaced by iron, calcium, or zinc, and compact forms of the mineral sometimes contain an admixture of manganese carbonate. It is flesh-red, light brownish-red, greenish or yellowish (when impure), and often black on exposed surfaces owing to oxidation. It is one of the less important ores.

*Franklinite*.—This is a manganese zinc-ore of great economic importance found at Franklin and Sterling, New Jersey, U.S.A. It is of variable composition, resembling magnetite in appearance. It crystallizes in the cubic system, occurring in octahedra, also in rounded grains, and massive. Its colour and streak are black. “Manganese zinc residuum,” used in large quantities in the United States in the manufacture of spiegeleisen, is a product consisting largely of iron and manganese oxides obtained from zinc volatilizing and oxidizing furnaces using New Jersey manganese zinc ores. The “residuum,” which contains about 12 per cent. of manganese, is smelted in a blast furnace.

*Manganese Silver-Ores*.—These are mixtures of manganese and iron oxides, with small amounts of silver and lead minerals, the iron content as a rule exceeding that of manganese, although it may be altogether absent. In the United States they occur in the Rocky Mountain and Great Basin regions, the principal producing locality being Leadville, Colorado. They are mined in large quantities, some varieties being sufficiently high in manganese to be classed with manganese iron ores, while too low in silver and lead to be valuable for either. When too poor in all three metals to be directly valuable for any one of them, these ores are smelted with silver ores for recovery of the silver and lead, the iron and manganese acting as fluxes.

## USES OF MANGANESE ORES

These may be summarized as, (1) Metallurgical, and (2) Chemical.

1. *Metallurgical Uses*

The steel industry consumes at least 90 per cent. of the world's output of manganese ores and manganiferous iron ores, nearly three-quarters of that consumption being in the production of manganese-iron alloys (spiegeleisen and ferro-manganese) and manganese-iron-silicon alloys (silico-spiegel) [3].

The manganese-iron, or manganese-iron-silicon, alloy, added to the steel as it runs into the ladle, in acid processes of steel manufacture, has effects on the metal which have been summarized as follows [3]:

(a) The prevention of over-oxidation of the steel by the reduction of small quantities of oxide in the bath.

(b) The addition of the requisite amount of manganese necessary in the finished steel.

(c) The hindering of the formation of blow-holes.

(d) The elimination of sulphur from the bath.

(e) The making of iron slag fluid and easy to run off.

(f) The addition of carbon to the bath, this, however, being incidental and not necessary. Allowance is made for the carbon added with the alloy when recarbonizing with pig iron, or by Darby's method in which powdered coal is utilized.

The quantity of manganese alloy added varies with the oxidation of the bath and the amount of manganese required in the finished product, but averages about 1 per cent. To produce 1 unit of metallic manganese in the alloy, roughly about  $2\frac{1}{2}$  units of manganese-ore proper are required. In addition to the large consumption of such ore for the manufacture of manganese alloys, the residues from manganiferous zinc ore (franklinite), and manganiferous iron-ores, are used for the production of spiegeleisen.

Ordinarily, spiegeleisen is used solely in Bessemer practice; but, to meet the curtailment of ferro-manganese supplies from Europe during the war, that lower alloy has been largely used in open-hearth steel-making in the United States,

as a substitute for ferro-manganese. Substitutes tried in Germany during the war, including calcium carbide, are understood to have, in general, failed to give the results hoped for.

H. M. Howe [4] points out that, apart from its deoxidizing and desulphurizing functions, the effect of manganese on the mechanical properties of steel appears to be due primarily to its retarding action on the transformations and on the coalescence of the micro-constituents into progressively coarser masses, which, while increasing the ductility, lessens the cohesion in general, including the hardness and the elastic limit, and thus lessens the effective strength. The retarding effect of manganese leads to finer structure and higher elastic limit, but lower ductility.

At the present time, practically all spiegeleisen and ferro-manganese are produced in the blast furnace. The manufacture of ferro-manganese in the electric furnace, as carried on at the recently constructed plant of the Iron Mountain Alloy Company, at Utah Junction, in Colorado, has been described by R. M. Keeney [5]. The furnace charge consists of a mixture of ore, coal and limestone in proper proportions for the reduction of manganese with a minimum slag loss. The plant contains one 1,200-k.w., three-phase furnace, and one 1,800-k.w., three-phase furnace, giving a total capacity of 12 long tons of ferro-manganese per 24 hours. Power is supplied by the Colorado Power Company. The furnaces operate at from 75 to 100 volts. The electrode consumption is high, ranging from 150 to 250 lb. per ton of product when using amorphous carbon electrodes. With dioxide ores, reduction takes place according to the reaction:  $\text{MnO}_2 + 2\text{C} = \text{Mn} + 2\text{CO}$ . Iron is added either as a constituent of the ore or in the form of iron turnings.

Where cheap water power is available, the electric furnace method is likely to become an important factor in the production of high-grade iron-manganese alloys, although the cost of producing such alloys is higher than in the blast furnace.

The principal manganese-iron and manganese-silicon alloys are as follows [3]:



—	Spiegeleisen.	Ferro-Manganese.	Silico-Spiegel.
	Per cent.	Per cent.	Per cent.
Metallic manganese . . .	5-20 <sup>1</sup> (usually 20)	20-85 <sup>2</sup> (usually 80)	18-20
Metallic iron . . . . .	70-85	8-60	60-70
Carbon . . . . .	4-5	6-7	1.5
Silicon . . . . .	0.5	0.5-1.0	10.0
Phosphorus . . . . .	0.035-0.055	0.055-0.25	0.05-0.06

<sup>1</sup> Usual limits in U.S. practice are 15 to 25 per cent. Mn.

<sup>2</sup> In U.S. practice, 60 to 80 per cent.

*Manganese-steel*, an alloy discovered by Sir Robert Hadfield in 1883, has been described by him, roughly, as an alloy of iron with about 12 per cent. of manganese and  $1\frac{1}{4}$  per cent. of carbon. For ordinary commercial use, this material is generally heat-treated, the treatment consisting in heating to about 1,000° C. and quenching in water. It is then very tough and strong, its tensile strength varying from about 54 to 63 tons per square inch, with 30 per cent. and in some cases 50 per cent. elongation. It is practically non-magnetic [6]. The alloy is largely used for castings where toughness, strength and resistance to abrasive wear are required (such as the wearing parts of rock-crushers, ball mills, crushing rolls, dredge buckets, etc., also conveyer chains and buckets, screens, railway crossings, etc.), and, as produced by various manufacturers, contains from 11 to 13.5 per cent. of manganese (usually from 12.5 to 13 per cent.), the proportion of carbon being from 1 to 1.3 per cent. Manganese-steel is so tough and hard that it cannot be machined. The highest grade ferro-manganese (containing 80 to 84 per cent. of manganese) is used in its production.

*Manganese-bronze* has been described as essentially an alloy of copper (75 to 76 per cent.), manganese (16 to 17 per cent.), and tin (5 to 6 per cent.). When of this composition it is tough and malleable, and of a brass-yellow colour. The compositions which will give high tensile strengths are, however, very variable. The average "manganese-bronze" of commerce contains from about 57 to 60 per cent. of copper, 38 to 41 per cent. of zinc, traces to usually not more than 1 per cent. of manganese, often from 0.25 to 1 per cent.

each of tin, iron and aluminium, and from 0·1 to 0·5 per cent. of lead. In some cases, not even a trace of manganese is shown on analysis, it having served its purpose as a deoxidizer, leaving behind the iron with which it was associated in the ferro-manganese added to the copper-zinc alloy. Aluminium up to 5 per cent. is stated to increase the strength and elasticity, giving the alloy a silver-white colour. The tensile strength of good commercial manganese-bronzes probably averages about 40 tons per square inch, with about 24 per cent. elongation. When forged, the alloy acquires great strength and toughness. Owing to its non-liability to corrosion, it is used for propellers and other parts of ships where that quality is of importance, while its tenacity renders it useful for other special purposes.

*Manganese German silver*, or "*silver-bronze*," commonly contains 60 parts of copper, 15 parts of zinc, and 40 parts of ferro-manganese (with 70 to 80 per cent. of manganese). For bearings, valves and cocks, the composition is frequently about 60 parts of copper, 10 parts of zinc, and 40 parts of ferro-manganese (containing 60 per cent. manganese). The addition of  $1\frac{1}{4}$  per cent. of aluminium is said to give the alloy good casting qualities and non-corrodibility. Nickel is frequently added, also a small proportion of silicon.

*Manganin*, an alloy used for electrical resistances, contains 82 per cent. of copper, 15 per cent. of manganese, and about 3 per cent. of nickel and iron.

## 2. Chemical Uses

(a) *Oxidizing Agents*.—Manganese dioxide is used in the manufacture of chlorine and bromine; in glass-manufacture, as a decolourizer; in dry electric batteries, Leclanché cells etc.; in driers for varnish and paint; and in the manufacture of permanganates of sodium and potassium, etc.

(b) *Colouring Materials*.—Manganese compounds are used in colouring glass, pottery, tiles and bricks; in calico-printing and dyeing; and for certain paints (brown, green and violet).

(c) *Flux*.—Manganese dioxide is used as a flux in the smelting of silver- and lead-ores.

*Chemical Requirements.*—For the production of chlorine, and, generally, for use as oxidizers, the peroxide ( $\text{MnO}_2$ ) is desired by the chemist, who employs manganese-ore in this connection solely for its content of oxygen, and wishes to have a cheap, portable and easily-treated material with the maximum percentage of that element. The important considerations are, (1) freedom from impurities that are soluble in acid used for the decomposition of the ore, and so cause an unnecessary consumption of acid; and (2) the amount of "available" oxygen and the ease with which it can be liberated. The presence of lime, in the form of carbonate, is objectionable, and this should not exceed about 2 per cent.; indeed, the impurity may even be required to be entirely absent. Ferrous compounds are also objectionable, since they act as reducing agents, but phosphorus is harmless in ores used for the production of chlorine. The chemist buys his ore at so much per unit (1 per cent.) of manganese peroxide. Japanese "brown-stone" ore, a pyrolusite, is specially suited for chemical purposes, and commands a higher price than others per unit of available peroxide. Generally, the manganese minerals best suited for chemical purposes are pyrolusite and psilomelane.

Before the war, high-grade Russian pyrolusite was almost exclusively used in this country for the manufacture of dry cells, Leclanché cells, etc., the specification calling for 86 per cent.  $\text{MnO}_2$  and not more than 1 per cent. of iron. In the United States the usual specifications of dry-battery manufacturers prior to the war were that the ore must contain at least 85 per cent.  $\text{MnO}_2$ , less than 1 per cent. of iron, and no copper. The worst features of California and other Western American manganese ores are the copper and high iron contents. Since the war began, ore of the desired high quality has not been obtainable in America in any considerable quantity, and makers of dry batteries in that country are now calling usually for ore containing at least 80 per cent.  $\text{MnO}_2$  (minimum available oxygen, 14.72 per cent.), less than 1 per cent. of iron, and less than 5 per cent. of copper, nickel or cobalt. The Russian supplies having been largely cut off, Indian ores have been employed in this country for the manu-



facture of Leclanché cells, with possibly some from other sources; but it has been found that these substitutes have generally given inferior results, the life of the cells being appreciably shorter. By careful selection, a uniformly good quality of ore for this purpose might be obtained in regular and sufficient quantities from Canada, and possibly from certain localities in India and other parts of the British Empire.

For the silica- or flint-glass industry, the ore must be as free as possible from iron, and the Russian (Caucasian) ores are specially suitable for this purpose. The usual specification by American flint-glass manufacturers requires an ore running from 78 to 85 per cent.  $\text{MnO}_2$ , with less than 1 per cent. of iron [7].

For chemical purposes generally, the basis of manganese peroxide demanded may be 60, 70 or even 80 per cent., the last being almost invariable in normal British practice.

*Metallurgical Requirements.*—The metallurgist buys manganese ore for its content of the metal, and does not require ores containing a high percentage of oxygen. A basis of 50 per cent. metallic manganese is common in Great Britain, with an allowance for each unit above and a penalty for each unit below that percentage. Ores required for the production of iron-manganese alloys should contain not less than 40 per cent. of manganese. Ores containing under 45 per cent. of that metal are saleable, but the metallurgist in Europe is becoming more and more insistent in demanding ores of high richness and purity, and desires an ore running as closely as possible to a minimum of 50 per cent. metallic manganese. Lime is not objected to, and indeed is sometimes paid for. Silica is penalized when it exceeds 8 or 9 per cent., the rate of deduction being normally about 3*d.* per unit of silica per ton for imported Caucasian ore. Phosphorus should not exceed 0.20 per cent., and may be penalized in England even when it exceeds 0.15 per cent., the penalty for each 0.01 or 0.02 per cent. of phosphorus above the maximum being agreed. In Germany, there is usually a penalty for manganese below 50 per cent., but not generally a bonus for richer ore. Alumina should be low, anything above 10 per cent. being highly

objectionable, especially in conjunction with high silica. Copper, lead, zinc and barium are objectionable when in any appreciable quantities.

For acceptance by the British Ministry of Munitions (March, 1918), manganese-ore should contain not more than 10 per cent. of silica, 10 per cent. of iron, or 0.1 per cent. of phosphorus; and the ore should contain the equivalent of at least 45 per cent. of metallic manganese, if it is to be used for making ferro-manganese.

Pyrolusite is required for the manufacture of dry cells. Other oxides low in silica are in great demand for the manufacture of ferro-manganese. Braunite is less desirable, having regard to its invariable association with silica, with which it is sometimes admixed to the extent of as much as 10 per cent.

In America, the prices per ton of 2,240 lb. paid by the Carnegie Steel Company, which govern the United States market for manganese ore, are based on a content of not more than 8 per cent. of silica or 0.20 per cent. of phosphorus. For each 1 per cent. of silica in excess of the limit, a deduction of 15 c. per ton is made, with fractions in proportion. For each 0.02 per cent. or fraction thereof of phosphorus in excess of the limit, a deduction is made of 2 c. per unit of manganese per ton. Payments for manganese and iron in domestic ores, delivered freight prepaid at Pittsburg or South Chicago, were made, at the outbreak of war, and so recently as July 31, 1917[8], according to the following schedule:

Content of Metallic Manganese in Ore.	Price per Unit.			
	Manganese.		Iron.	
	August 5, 1914.	July, 1917.	August 5, 1914.	July, 1917.
Per cent.	Cents.	Cents.	Cents.	Cents.
Over 49 . . .	26	100	5	Not specified in statement quoted.
46-49 . . .	25	98	5	
43-46 . . .	24	95	5	
40-43 . . .	23	90	5	

Ores containing less than 40 per cent. of manganese, or more than 12 per cent. of silica, or more than 0.225 per cent.

of phosphorus, are subject to acceptance or rejection at the buyer's option. Settlements are based on analysis of samples dried at 100° C.

Not only the composition but also the physical properties and the condition as delivered are of importance in manganese-ores.

For chemical purposes, the mineral should be sufficiently porous to allow of acid percolating through it, but of such density as to prevent crumbling in the stills. Lump ore (pyrolusite) from certain, somewhat limited, portions of the Caucasian deposits is particularly well suited for the purposes of the chemist, as also for those of the glass-maker; but the annual production of this special quality is comparatively small, and there is a good market for Indian pyrolusite and psilomelane for both these purposes.

When intended for metallurgical purposes, the ore is usually shipped as ballast, and should be sufficiently hard and tough to withstand excessive disintegration in shipment. Indian and Brazilian ores are very suitable from this point of view, the proportion of rubble and fines produced between mine and destination being comparatively unimportant. Caucasian ores often arrive with 80 per cent. of fines. For smelting purposes, the ore should be in lumps, with a minimum of fines and dust, which block interstices in the furnace charge required for the passage of gases, and are driven into the flues, necessitating frequent blowing-out.

Until November, 1909, manganese-ores for use in the iron and steel industry were divided into three grades for commercial purposes: first grade, 50 per cent. Mn and upwards; second grade, 47 to 50 per cent. Mn; and third grade, 40 to 47 per cent. Mn. From December, 1909, second-grade ore has been limited to 48 to 50 per cent. Mn, while the third grade has been restricted to ores with from 45 to 48 per cent. Mn [9].

The price per unit of manganese, and consequently per ton of manganese-ore, obtained on delivery c.i.f. at port of destination, is at present abnormally high owing to the war; in pre-war times it fluctuated between 9½*d.* and 12½*d.* per unit for first-grade ore c.i.f. at United Kingdom ports between January, 1910, and July, 1914, the price per unit at the latter



date being from  $9\frac{1}{4}d.$  to  $9\frac{1}{2}d.$  The price for second-grade ore similarly delivered was generally  $\frac{1}{4}d.$  per unit less than that for first-grade ore, a further reduction of  $\frac{1}{4}d.$  being made for third-grade ore.

There are no current quotations in this country for manganese-ores, but the price for Indian c.i.f. United Kingdom ports in January, 1918, was nominally  $41\frac{1}{2}d.$  per unit, on a 50 per cent. Mn. basis, this high figure being due to the abnormal freight rates. In March, 1918, the f.o.b. price of manganese ore in India was about  $8d.$  per unit (pre-war price,  $7d.$ ), the c.i.f. price in the United Kingdom being  $36d.$  per unit for manganese-ore with 50 per cent. metal content (pre-war price,  $11d.$  per unit). The c.i.f. price in the United Kingdom was still about  $36d.$  per unit in March, 1919.

*Relative Values of Indian and Foreign Ores.*—Analyses of a large number of cargoes of manganese ores and manganiferous iron ores landed at Middlesbrough during the years 1897–1906 are tabulated in *Memoirs, Geol. Surv. Ind.*, **37** (1909). The cargoes represented the manganese ores of India, Russia (Caucasus), Brazil and Chile, and the manganiferous iron ores of Greece and Spain. The following is a general summary of the analytical results :

*Moisture.*—The Indian ores contained less moisture than those of the other countries, twenty-two cargoes from the Central Provinces (with possibly some ore from Jhabua and Panch Mahals) containing 0.71 per cent. and four cargoes from Vizagapatam 0.76 per cent. of water. Some of the foreign ores contained such large quantities of moisture (Caucasus, 8.67 per cent. ; Brazil, 11.35 per cent. ; and Spain, 8.44 per cent.) that it was necessary to reduce the analyses to their condition when dried at  $100^{\circ}C.$  before any fair comparison could be made.

*Manganese.*—The Indian cargoes stood first as regards manganese contents, with Brazil a close second.

*Silica.*—The percentage was lowest in the Brazilian ores, the Indian coming next.

*Phosphorus.*—The Russian ores contained most phosphorus, Indian following. (The percentage of phosphorus in the Indian ores has since shown a tendency to increase, and, as

now exported, the phosphorus content somewhat exceeds that of the Russian ores as shipped.)

*Iron.*—The Indian ores contained much less iron than the manganiferous iron ores of other countries; but of the true manganese ores they contained the highest amounts of iron, in spite of the fact that they also contained the highest percentages of manganese.

The high iron content of the Indian ores is a point for or against them, according to the use to which the ores are to be put. High iron contents make it more difficult to manufacture the very highest grades of ferro-manganese from the Indian ores (a point which should not be overlooked when considering the suggested placing of an embargo on the export of manganese-ores from India and shipping locally-made ferro-manganese); but, if the very highest grades are not required, the iron is of considerable value. Both iron and manganese are of use in such case, and the buyer obtains the following totals of Mn + Fe when purchasing the ores of the different countries, assuming them to be of the average values shown by these analyses [10]:

						Mn + Fe per cent.
India .	.	.	.	.	.	57·17
Brazil .	.	.	.	.	.	54·09
Russia .	.	.	.	.	.	50·41
Chile .	.	.	.	.	.	48·40
Greece .	10	.	.	.	.	47·99
Spain .	10	.	.	.	.	44·27

## CHAPTER II

### SOURCES OF SUPPLY OF MANGANESE ORES

#### (a) BRITISH EMPIRE

##### EUROPE

UNITED KINGDOM.—The manganese ores originally used in this country came from deposits in North Wales, where rhodochrosite predominates, and from the West of England, where the chief ores are pyrolusite and rhodonite. Manganese-ores occur also in Derbyshire, Warwickshire and Cumberland, and in Scotland ; but, from the evidence available at present, it appears unlikely that any great quantity of such mineral could be obtained from those areas[11]. The deposits in Devon and Cornwall are not exhausted, but they cannot be worked profitably even at current prices. The manganese ore now produced in Great Britain is obtained partly in the Lley Peninsula, Carnarvonshire, and partly in Merionethshire. The great expansion in the use of manganese has rendered domestic sources utterly inadequate for British metallurgical requirements ; and, as supplies of far richer ore can readily be obtained from other countries, it is highly improbable that the home deposits will ever be extensively worked.

*Carnarvonshire.*—In the Lley Peninsula, there are three mines, namely the Nant, the Benallt, and the Rhiw. At the Nant Mine, the undecomposed ore contains manganese in the form of carbonate with a small proportion of silicate, but at the outcrop this has been altered into a hydrated black oxide. It occurs as a bed, from 10 to 20 feet in thickness, intercalated among the Ordovician (Lower Silurian) shales. The beds are much faulted and the ore is often slickensided. The



ore has been stated [12] to average from 30 to 36 per cent. manganese, 7 to 10 per cent. iron, 18 per cent. silica, and 0·3 to 0·5 per cent. phosphorus; but, according to Home Office statistics, the average yield is only about 30 per cent. manganese, with 10 per cent. iron. Both at Nant and at Rhiw there are extensive intrusions of syenite and greenstone in the shales. The Nant mine is worked through an incline from which several levels have been driven.

At Benallt, where there are several beds of manganese ore, the shales have been folded into an anticline. This mine and the Rhiw have been exploited by adits and shafts, as well as by open workings.

The total output from these mines since 1892 amounts to over 80,000 tons. Production in recent years is tabulated below.

*Merionethshire.*—Only a few tons of manganese ore are obtained annually from this county, where it occurs mostly as a bed of mixed carbonate and silicate between the grits and conglomerates of the Lower Cambrian formation. In the Llanbedr district, the bed varies in thickness from 10 to 20 inches, and is encrusted near the surface, and on the joints and cracks which traverse it, with black oxide of manganese, a decomposition product containing from 20 to 32 per cent. of manganese. This weathered crust, which consists essen-

*Output and Value of Manganese Ore from North Wales<sup>1</sup>*

Year.	Carnarvonshire.		Merionethshire.		Total.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£
1912 . . .	3,934	3,136	236	235	4,170	3,371
1913 . . .	5,291	3,977	102	95	5,393	4,072
1914 . . .	—	—	—	—	3,437 <sup>2</sup>	2,931
1915 . . .	—	—	—	—	4,640	4,640
1916 . . .	—	—	—	—	5,140	6,020
1917 . . .	10,164	—	2,930	—	13,094	—

<sup>1</sup> Home Office Statistics. The 1917 figures are from returns made to the Ministry of Munitions. Home Office Statistics (*Mines and Quarries*, Pt. 1, 1917) give a total of only 9,942 tons.

<sup>2</sup> Practically all from the Nant mine, Carnarvonshire, in this and following years.

tially of pyrolusite, is the richest part of the ore, and formerly it only was worked, the carbonate and silicate being rejected as useless. The ore when mined is broken into lumps about 2 inches across, and sent to glass-works at St. Helens, Lancashire, the use of the mixed carbonate and silicate in that industry having been found valuable. The bed of ore is traceable along the sides of the valleys of two rivers for many miles, and has been exploited in a number of shallow open-works, below which there appear to be considerable reserves.

*West of England.*—The ores formerly produced in this part of Great Britain were obtained chiefly from the neighbourhood of Launceston, in Cornwall, and Brenton, in Western Devon, and consisted chiefly of pyrolusite and rhodonite. The discovery of large deposits in Germany, about the middle of last century, lowered the price of manganese-ore to such an extent that the mines in the West of England were closed down; and, with one or two exceptions, these have since been worked only intermittently. A description of the occurrences would serve no useful purpose, as the manganese-ore industry in this part of Great Britain is unlikely to become of importance.

*Derbyshire.*—A few hundred tons of wad have been obtained from near Winster, where the mineral occurs in flats, pipes and pockets in the Carboniferous limestone, but so irregularly that it cannot be mined systematically. A shallow shaft is sunk, and the mineral is worked from this as far as practicable. The wad occurs with ochre and some barytes, and is carted to colour-works at Matlock. It is inferior in grade to the imported material. Possibly 10 tons a week could be raised at this place. The mineral is said to occur at other localities in the district.

*Scotland.*—Ores of manganese have been worked only on a small scale in Scotland, and no returns of production are available. The manganese minerals recorded as occurring include psilomelane, manganite and wad.

*Ireland.*—Manganese ore was formerly obtained in some quantity at Sutton, in County Dublin, and occurrences are reported from many other localities in Ireland; but no deposits of importance are known.

The most productive years in the history of manganese ore mining in Great Britain were 1905-1907, the annual output varying in that period from 14,474 tons up to 22,762 tons.

### IMPORTS OF MANGANESE-ORE AND MANGANIFEROUS IRON-ORE INTO THE UNITED KINGDOM

Diagram 2, p. 27, and the tables on pp. 28 and 29 show the quantity and value of (1) Manganese Ore and (2) Manganiferous Iron Ore imported into the United Kingdom during the years 1913-1916, together with the chief countries of origin.

It will be seen that, while imports from Russia were entirely cut off in 1915 and 1916, imports from India not only improved in those years, but actually exceeded those for the last pre-war year. In this connection, however, it must be pointed out that shipments to the United States during 1915 and 1916 were abnormally low, while, of course, the Belgian market was lost.

The great increase in values since the outbreak of the war has been chiefly due to abnormally high freight.

The effect of the war on both the amount and the cost of manganiferous iron ore imported into the United Kingdom is clearly shown in the table. The average value per ton in 1913 was 16/3·6, while in 1916 it was 35/8·4.

The comparative unimportance of manganese ore production in the United Kingdom is clearly shown in the following table :

Year.	U.K. Production. <sup>1</sup>		U.K. Imports. <sup>1</sup>	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
1859 <sup>2</sup> . . .	1,231	3,693	Not stated	Not stated
1873 . . .	8,671	57,766	25,777	150,983
1883 . . .	1,287	2,976	22,362	82,314
1893 . . .	1,336	762	121,773	335,984
1903 . . .	818	656	231,864	466,327
1913 . . .	5,393	4,072	601,177	1,295,113
1914 . . .	3,437	2,931	479,435	1,001,654

<sup>1</sup> Home Office Statistics. Mines and Quarries Reports.

<sup>2</sup> Earliest year for which figures are available.



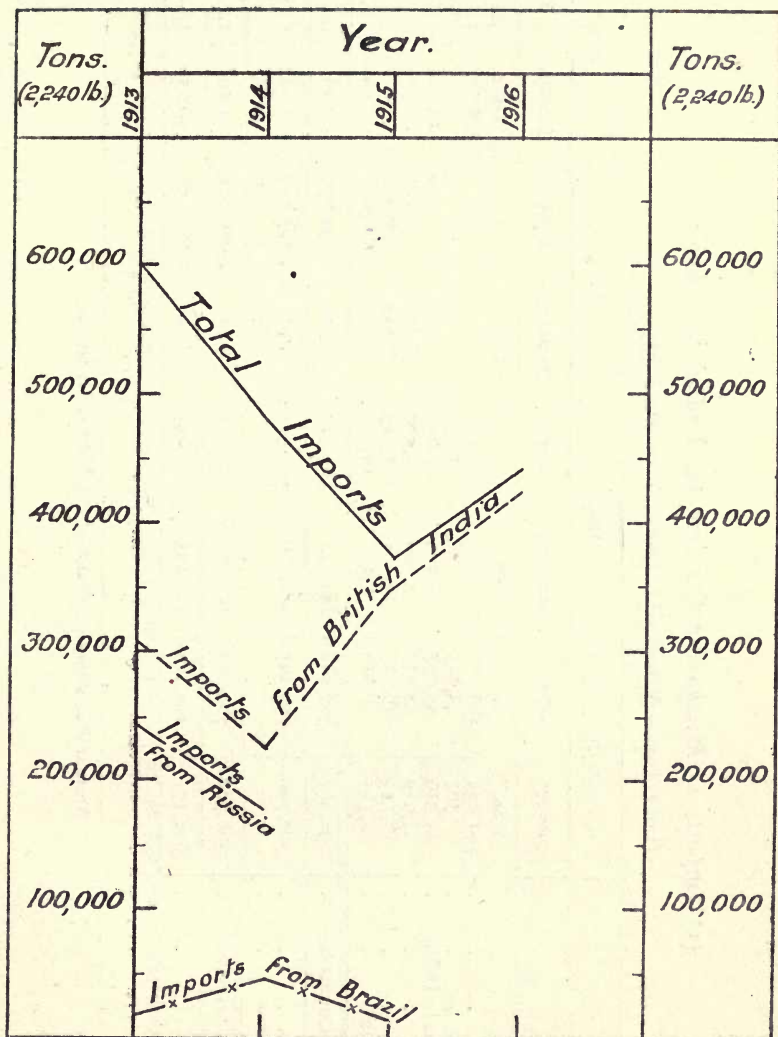


DIAGRAM 2.—IMPORTS OF MANGANESE-ORE IN THE UNITED KINGDOM, TOTAL AND FROM CHIEF PRODUCING COUNTRIES (1913-1916).

(I) Imports of Manganese Ore into the United Kingdom <sup>1</sup>

(Long Tons.—Values c.i.f. United Kingdom Port)

From	1913.			1914.			1915.			1916.		
	Quantity.		Value.	Quantity.		Value.	Quantity.		Value.	Quantity.		Value.
	Tons.		£	Tons.		£	Tons.		£	Tons.		£
Russia . . . . .	241,894		463,151	177,646		323,297	—		—	—		—
Germany . . . . .	307		1,823	188		1,055	—		—	—		—
Portuguese Possessions in India . . . . .	24,710		55,255	20,275		44,850	250		500	13,011		77,935
Spain . . . . .	3,919		13,617	3,596		10,268	8,856		26,725	2,809		19,169
Brazil . . . . .	18,792		46,227	46,494		101,825	14,515		66,514	—		—
Other Foreign Countries . . . . .	2,765		6,915	6,150		13,045	89		938	541		8,716
Total from Foreign Countries . . . . .	292,387		586,988	254,349		494,340	23,710		94,677	16,361		105,820
British India . . . . .	308,790		708,125	225,086		507,314	348,954		1,085,849	421,443		2,200,778
Other British Possessions . . . . .	—		—	—		—	60		232	2,855		15,802
Total from British Possessions . . . . .	308,790		708,125	225,086		507,314	349,014		1,086,081	424,298		2,216,580
Total . . . . .	601,177		1,295,113	479,435		1,001,654	372,724		1,180,758	440,659		2,322,400
Average Value . . . . .	43/1			41/9.4			63/4.3			105/4.8		

<sup>1</sup> Annual Statement of Trade of the United Kingdom.

(2) Imports of Manganiferous Iron Ore into United Kingdom<sup>1</sup>

(Long Tons.—Values c.i.f. United Kingdom Port)

From	1913.		1914.		1915.		1916.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£	Tons.	£
Algeria . . . . .	3,797	3,757	16,857	13,647	30,334	36,311	30,861	51,468
Spain . . . . .	188,196	149,632	120,249	97,501	83,639	98,528	47,137	77,356
Greece . . . . .	13,499	10,056	17,859	11,448	17,986	24,045	—	—
Other Foreign Countries . . . . .	6,152	9,050	7,811	11,572	1,289	2,191	—	—
Total from Foreign Countries . . . . .	211,644	172,495	162,776	134,168	133,248	161,075	77,998	128,824
Total from British Possessions (British India) . . . . .	—	—	2,717	6,140	5,720	15,423	3,994	17,551
Total . . . . .	211,644	172,495	165,493	140,308	138,968	176,498	81,992	146,375

<sup>1</sup> Annual Statement of Trade of the United Kingdom.



*Exports of Spiegeleisen, Ferro-manganese and Ferro-silicon from the United Kingdom*<sup>1</sup> (1913-1916)

(Long Tons.—Values f.o.b. United Kingdom Port)

To	1913.	1914.	1915.	1916.
	Tons.	Tons.	Tons.	Tons.
Russia . . . .	3,577	1,355	817	1,454
Sweden . . . .	6,232	3,904	2,595	2,505
Germany . . . .	3,553	3,561	—	—
Netherlands . . . .	1,724	1,572	168	105
Belgium . . . .	11,355	6,185	—	—
France . . . .	9,600	3,110	6,939	11,661
Spain . . . .	3,624	1,939	4,534	4,355
Italy . . . .	4,495	3,123	9,807	10,849
Japan . . . .	3,599	1,785	3,346	4,163
United States of America	116,660	79,498	60,882	81,188
Other Foreign Countries	2,065	1,617	1,486	1,040
Total to Foreign Countries . .	166,484	107,649	90,574	117,320
Value . . . .	£1,511,261	£915,189	£1,190,151	£2,522,471
Canada . . . .	9,996	3,360	8,349	9,587
Other British Possessions	2,439	779	4,015	494
Total to British Possessions . .	12,435	4,139	12,364	10,081
Value . . . .	£119,454	£34,988	£176,304	£249,813
Grand Total Tons	178,919	111,788	102,938	127,401
„ „ Value	£1,630,715	£950,177	£1,366,455	£2,772,284
Average value per ton . .	182/3·4	169/11·9	265/5·9	435/2·5

<sup>1</sup> Annual Statement of the Trade of the U.K. (1916).

The increase in values of the exports was due chiefly to the increased cost of the imported manganese ore from which the iron-manganese alloys were produced.

The production of Spiegeleisen, Ferro-manganese, Ferro-silicon, etc., in the United Kingdom during these years was 324,145, 326,354, 255,484 and 291,845 tons respectively, the percentages of the production exported being 55·2, 34·25, 40·3 and 43·65 respectively (*Statistical Report for 1916*; Iron, Steel, and Allied Trades Federation Statistical Bureau).

*Exports of Foreign and Colonial Manganese Ore from the  
United Kingdom*

(Long Tons.—Values f.o.b.)

To	1913.	1914.	1915.	1916.
	Tons.	Tons.	Tons.	Tons.
Belgium . . . . .	8,440	6,450	—	—
France . . . . .	—	—	128	—
United States of America . . . . .	309	412	—	—
Other Foreign Countries . . . . .	15	63	76	25
Total to Foreign Countries . . . . .	8,764	6,925	204	25
Value . . . . .	£34,786	£28,884	£3,022	£755
Total to British Possessions . . . . .	1,195	88	84	10
Value . . . . .	£3,433	£348	£1,270	£82
Grand Total . . . . .Tons	9,959	7,013	288	35
„ „ . . . . .Value	£38,219	£29,232	£4,292	£837
Average value per ton . . . . .	76/9	83/4.4	297/-	478/3.4

*Exports of Foreign and Colonial Spiegeleisen, Ferro-manganese  
and Ferro-silicon from the United Kingdom<sup>1</sup>*

(Long Tons.—Values f.o.b.)

To	1913.	1914.	1915.	1916.
	Tons.	Tons.	Tons.	Tons.
France . . . . .	—	—	522	—
Japan . . . . .	—	—	—	101
Other Foreign Countries . . . . .	56	59	134	111
Total to Foreign Countries . . . . .	56	59	656	212
Value . . . . .	£415	£581	£9,999	£7,123
Total to British Possessions . . . . .	—	—	—	6
Value . . . . .	—	—	—	£276
Grand Total . . . . .Tons	56	59	656	218
„ „ . . . . .Value	£415	£581	£9,999	£7,399
Average value per ton . . . . .	148/2.6	196/11.4	304/10.2	678/9.7

<sup>1</sup> Annual Statement of Trade of the United Kingdom

## ASIA

*British North Borneo.*—Discoveries of manganese ore deposits in this State have been noticed in former publications of the Imperial Institute [13], where it is mentioned that the British North Borneo Exploration Company had presented specimens of manganese-ore to the Institute, these coming from a deposit situated close to Taritipan, near the southern end of Marudu Bay, on the north-west coast. Outcrops of the ore were reported to have been met with over an area of about 12 square miles. Analyses of samples from various parts of the deposit indicated that average shipments would contain manganese dioxide equivalent to 49 to 51 per cent. of metallic manganese, 15 per cent. of silica, 0.35 per cent. of sulphur, and 0.03 per cent. of phosphorus. The silica was rather high, but the sulphur and phosphorus were decidedly low. A picked cargo would contain from 8 to 10 per cent. of silica, and the equivalent of from 51 to 53 per cent. of manganese, and it was estimated that an annual export of from 40,000 to 50,000 tons could be easily maintained.

The attention of iron and steel makers in Germany was soon directed to these deposits, and a description of them appeared in that country [14], in which it was stated that, from the extent of the deposits as then known, the British North Borneo Exploration Company would be able to produce 50,000 tons per annum for at least twenty-five years. The ore was said to consist mainly of psilomelane, containing on an average 50.4 per cent. of metallic manganese and 14.6 per cent. of silica, to be free from copper, arsenic, nickel and baryta, and to contain on an average less than 0.05 per cent. each of sulphur and phosphorus.

Extensive deposits of limonite of fairly good quality were said also to occur in the district, together with an abundance of pure limestone suitable for use as a flux, while there was an unlimited supply of timber for mining purposes, and labour was abundant and cheap. Anthracite was known to occur at the surface on an island off the north-east coast, and it was regarded as possible, at the date mentioned, that investigations then proceeding might reveal the existence of



considerable supplies of suitable fuel within easy reach, and as probable that in any case the exploratory work then in progress would lead to the establishment of a considerable mining industry. Several shiploads of ore had already reached Europe, and contracts had been arranged for further supplies.

No output from British North Borneo has hitherto been included in available statistics of the world's production of manganese-ore, and there is no reference to that mineral in recent issues of the *Official Gazette* consulted; but it would certainly appear that the North Borneo deposits deserved thorough investigation, and no information appears to have been published showing that this has been undertaken. An enquiry addressed to the British North Borneo Company has elicited the information that there has been no production of manganese-ore in the State since the year 1906.

*Sarawak.*—Manganese ores are known to occur in the districts Sarawak proper (Bidi), Lundu and Rejang, but nowhere in workable quantity [15].

*Federated Malay States.*—A sample of manganese ore obtained from a mine at Tambun was analysed at the Imperial Institute in 1908. It consisted partly of a soft brown maniferous earth and partly of hard black lumps of manganese ore. The earthy portion appeared to preponderate, and this had broken up to such an extent that the sample consisted largely of dust. Analysis showed it to contain the equivalent of 38·16 per cent. of metallic manganese; 13·58 per cent. of silica; 8·73 per cent. of iron; 9·27 per cent. of alumina; 0·109 per cent. of phosphorus; with 9·64 per cent. of organic matter and combined water, and only a trace of lime. The ore was inferior to the general average of third-grade manganese ores on the market, and material in the condition of this sample would not repay shipment to Europe. The poor quality was, however, due to the inclusion of the brown earthy material with the lump ore. If the latter could be worked separately or selected, a first-grade manganese ore might be obtained which would find a ready market in this country.

*India.*—Manganese ore mining began in India in 1892, in

the Vizagapatam district, Madras Presidency, 674 tons being produced in that year. In 1900, the Central Provinces commenced production with an output of 47,257 tons; and, in 1903, Central India became a contributor to the Indian production, with an output of 6,800 tons, the total output from these three localities in that year amounting to 177,821 tons[16]. In 1913, the production for the whole of India amounted to 815,047 tons.

The Indian manganese-quarrying industry reached its zenith in 1907 (when the production exceeded 900,000 tons), its expansion being due largely to great activity in the steel trade of Europe and the United States, and, to a smaller extent, to political disturbances in the Caucasus. From 1908-1911, India ranked first in manganese-ore production, Russia subsequently resuming the position and retaining it until the outbreak of the war, when her foreign markets were cut off. In the decade 1903-12, 37 per cent. of the world's total output of manganese-ore was supplied by Russia, 20 per cent. by British India, and 12 per cent. by Brazil.

The Indian ore, on account of its hard lump form, is much more suitable for blast furnaces than the softer and more friable ores of the Caucasus; and, owing to more careful selection, it is exported in more uniform quality than that characterizing Russian shipments. It consists mainly of psilomelane, with an important amount of braunite.

The geological relations of Indian manganese ores are fully discussed in *Memoirs, Geol. Surv. Ind.*, 1909, 37, and in *Records, Geol. Surv. India*, 1915, 46; and the following brief account of the distribution and mode of occurrence of the deposits has been abstracted from those authoritative sources.

The deposits of economic value are divided into three main groups:

(a) Those associated with a series of manganiferous intrusives, known as the kodurite series. (Developed typically in Vizagapatam.)

(b) Those associated with rocks of Dharwar age—the manganiferous facies of which is known, when containing spessartite-garnet, as the gondite series. (Found in Gangpur,

Panch Mahals, Jhabua, Balaghat, Bhandara, Chindwara and Nagpur.)

(c) Those occurring as lateroid replacement masses on the outcrops of Dharwar rocks. (Found in Singhbhum, Jubbulpore, Bellary, Sandur, Chitaldrug, Kadur, Shimoga and Tumkur; also in Goa, Portuguese India.)

With the exception of the Vizagapatam deposits, all the important manganese ore deposits of India occur in one or other of the various phases of the Dharwar rocks.

(a) *The Kodurite Group*.—In the Vizagapatam district, this series occurs associated with other Archæan crystalline rocks, and it is held to be of igneous origin. The typical rock, kodurite, is composed of potash-felspar, spandite (a garnet) and apatite. The manganese ore bodies are often extremely irregular in size and shape, frequently showing no definite strike or dip. In other cases, they have a well-marked dip and strike, and apparent bedding, which probably represents original banding in the parent rock; for much of the ore has been deposited so as to replace metasomatically the pre-existing rock:

The largest of the ore-bodies in the Vizagapatam district occurs at Garbham, this being about 1,600 feet in length and measuring 167 feet across its thickest section, 100 feet of its thickness being ore and the remainder lithomarge, wad, etc. The only other very large deposit in the district is at Kodur (the first to be worked in India), but this is really a series of scattered ore-bodies in lithomarge.

The ores of the district are mainly psilomelane with minor amounts of pyrolusite, braunite, etc. They are usually second and third grade, and can be divided into manganese ores (about 40 per cent. Mn) and ferruginous manganese ores (below 40 per cent. Mn). They are characterized by high iron and phosphorus contents, and comparatively low silica.

(b) *The Gondite Group*.—This series is developed typically in several districts in the Central Provinces, but has also been found in some other areas. It is composed of metamorphosed mangiferous sediments of Dharwar age, and is characterized by the presence of various mangiferous silicates, the most important being manganese-garnet and



the manganese-pyroxene, rhodonite. The garnet occurs commonly as a rock composed of spessartite and quartz, this rock being named gondite.

Forming an integral portion of the same masses as the gonditic rocks, there are at many places bodies of manganese ore often of large size and first grade, some in the Central Provinces being the most valuable in India and in quality second to none found in other countries.

The ore-bodies occur as lenticular masses and bands intercalated in the quartzites, mica-phyllites and mica-schists of the gonditic series, and are often well bedded parallel with the strike of the enclosing rocks, several being often disposed along the same line of strike, suggesting that they have all been produced from the same bed of manganiferous sediment. With the enclosing rocks, the ore-bodies have often suffered repeated folding.

The ore-bodies are often of large size, the Balaghat deposit being  $1\frac{3}{4}$  mile in length, that at Manegaon in the Nagpur district  $1\frac{1}{2}$  mile; while a band running through Jamrapani, Thirori and Ponia, in the Balaghat district, is exposed more or less continuously for nearly 6 miles. There is no evidence that the ore-bodies are anywhere really more than from 45 to 50 feet in thickness, greater apparent size being probably due to duplication by folding. The ore-band is often much thinner, but this may also be due to folding. The depth to which the ore-bodies extend is unknown, but, in many cases, it is almost certain that they persist to at least from 100 to 400 feet below the outcrop, and it is very probable that some deposits of the Central Provinces extend to depths considerably greater.

The typical ores of the Nagpur-Balaghat area of the Central Provinces consist of mixtures of braunite and psilomelane, the most typical being a hard fine-grained ore composed of these two minerals. The ores as exported are nearly all of first grade, although at times of high prices a small quantity of second-grade ore is shipped. The chief characteristics of these first-grade ores, as exported, are high manganese content (usually 49 to 54 per cent.), moderately high iron (usually 4 to 8 per cent.), rather high silica (usually about 6 to 9 per cent.—largely due to braunite), and fairly low phosphorus (about 0.07 to 0.14 per cent.).

In addition, manganese ores are sometimes found in the Central Provinces in association with crystalline limestones, either as lines of nodules or, more rarely, as fairly definite beds in the limestone. In general, these ores are not found profitable to work, although, where the bed is of exceptional thickness, they may yield a profit when prices are high.

(c) *The Lateroid Group*.—In several parts of India, manganese-ore deposits are found on the outcrops of rocks of Dharwar age, associated in such a manner as to indicate that the ores were formed by the replacement at the surface of Dharwar schists, phyllites and quartzites. The masses of ore thus formed often contain considerable quantities of iron ore; and every gradation occurs from manganese-ores, through ferruginous manganese ores and manganiferous iron ores, to iron-ores. The manganese-ores are pyrolusite, psilomelane, wad, and more rarely pseudo-manganite and manganite. The iron-ores are limonite and earthy hæmatite. The manganese-ores are high in iron, low in silica, and often very low in phosphorus. The manganese is usually correspondingly low, so that the mineral won consists mainly of second-grade manganese ores and third-grade ferruginous manganese ores. Such deposits will be worked to greatest advantage when a market can be found for the iron ores and the manganiferous iron ores, as well as for the manganese ores.

Lateroid deposits are irregular, often more or less cavernous and rugged, and bear considerable resemblance to ordinary laterite. Manganese-ores are sometimes found in true laterite, but such ores are rarely of much economic value.

#### ANALYSES OF INDIAN MANGANESE-ORES

A good idea as to the quality of the ores occurring in different parts of India can be obtained from the range and mean value of analyses of manganese-ores and manganiferous iron-ores, as compiled by the Geological Survey of India. Space does not allow of adequate quotation, but it may be said that with one or two exceptions, notably the Panch Mahals, the range of analyses agrees very well with the composition for which buyers stipulate when contracting for various Indian ores. This is shown in the following table:





A comparison has already been made of the composition of Indian and foreign ores landed in England during the years 1897-1906 (see p. 21). These cargoes included 26 from India, and the following table summarizes the analyses of the ore [17]:

Probable Source of Ore.	Central Provinces, and possibly Jhabua and Panch Mahals.	Vizagapatam.
Number of Cargoes.	22	4
	Per cent.	Per cent.
Manganese . . . .	51·31	45·95
Iron . . . . .	5·53	10·29
Silica . . . . .	6·13	3·10
Phosphorus. . . .	0·096	0·291
Moisture . . . . .	0·71	0·76

Such information as is available points to a slight decrease in the manganese contents of these ores with depth, and a slight increase in the silica and phosphorus contents, this being regarded as probably indicating a certain amount of surface modification of the ores. There is at present no reason for supposing that this deterioration will necessarily be progressive with depth [18]. The percentage of phosphorus in the Indian ores may now average as much as 0·12 per cent., or perhaps a little more than this.

No fresh areas with manganese-ore deposits of importance have been discovered in India for some years past, nor have any important new deposits been located in recent years in areas already under exploitation. Many of the smaller and poorer deposits have been abandoned. Quarries have in many cases been considerably deepened, and preparation has been made for the continuance of work on open-cast lines. There appears to be no intention to work any of the deposits by underground mining methods. No boring has been undertaken to acquire information as to the persistence of the deposits in depth, and it is suggested that exploiting companies, in many cases, might with advantage adopt a course of procedure which is so commonly practised in other mining industries [18].

Two of the principal companies operating in the Central

Provinces are now stacking low-grade ores separately from smalls, and a market has been obtained for the latter down to the size of a small walnut. Very small ore proves to be of low grade in India, and has generally been regarded as waste. Low-grade ore that occurs separately in the mines is not at present quarried [18].

*Production of Manganese Ore in British India (1909-16) \**

(Long Tons)

Year.	1 Bihar and Orissa.	2 Bombay.	3 Central India.	4 Central Provinces.	5 Madras.	6 Mysore.	Totals for whole of British India.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1909 . .	55,060	17,657	10,324	381,285	138,454	41,880	644,660
1910 . .	41,958	30,921	12,664	552,239	120,607	42,518	800,907
1911 . .	25,152	45,330	7,319	445,051	125,865	21,573	670,290
1912 . .	27,173	43,538	5,652	414,542	117,246	24,929	633,080
1913 . .	11,215	40,914	6,814	649,307	96,296	10,501	815,047
1914 . .	6,070	27,223	6,642	564,890	60,018	18,055	682,898
1915 . .	507	26,915	366	399,215	288	23,125	450,416
1916 . .	2,834	55,876	—	558,828	2,755	24,911	645,204
Total .	169,969	288,374	49,781	3,965,357	661,529	207,492	5,342,502
Provincial Averages	21,246	36,047	6,223	495,670	82,691	25,936	667,813

Notes: 1. Gangpur. 2. Panch Mahals. (Ratnagiri produced 525 tons in 1910.) 3. Jhabua. 4. Balaghat, Bhandara, Chindwara and Nagpur. (Jubbulpore produced 300 tons in 1910.) 5. Sandur and Vizagapatam. (Bellary produced 500 tons in 1910.) 6. Chiefly Shimoga. (Chitaldrug produced 5,856 tons in 1909 and 1,803 tons in 1910; Kodur produced 3,307 tons in 1909.)

\* *Statistical Abstract relating to India*, 49, and *Rec. Geol. Surv. Ind.*, 46, 47, 48. (See refs. [19] and [20].)

The figures in the above table, except in a few cases, represent tonnages won, and not tonnages railed.

The returns for 1915 show the serious effect of the war on the Indian manganese ore industry. The total production in 1917 was 590,813 tons. (See Diagram 3.)

Comparing the quinquennium 1909-13 with the previous five years, a substantial increase is shown, the average annual production of manganese-ore for the whole of India for 1904-8 having been only 509,143 tons. The Central Provinces is by far the most important producer of manganese ore, and the four chief producing districts of that province

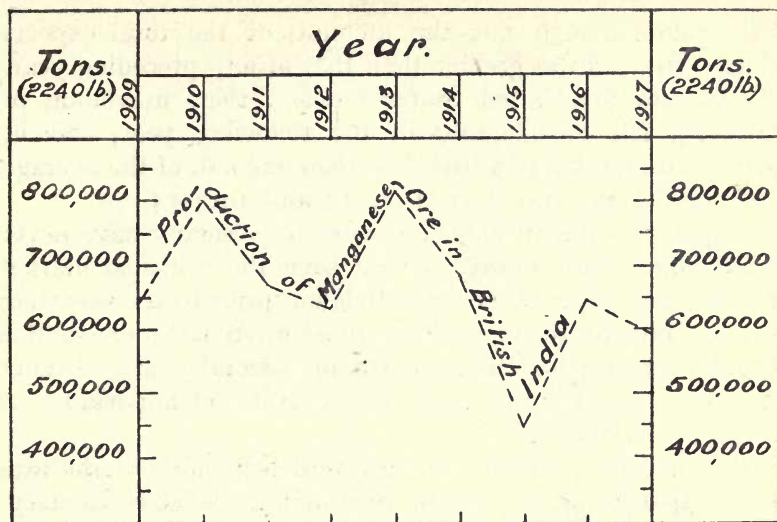


DIAGRAM 3.—PRODUCTION OF MANGANESE-ORE IN BRITISH INDIA (1909-1917).

are responsible for the greater part of the increase shown, the Chindwara district taking its proper place for the first time in 1913, owing to the extension of the Bengal-Nagpur Railway into the Sausar tahsil. Bombay Presidency also shows a large percentage increase, due to the opening up of deposits in the Panch Mahals. Gangpur State in Bihar and Orissa shows a six-fold increase in the average annual production, but the figures record a change from a maximum in 1909 to a minimum in 1913. The Madras Presidency shows a small increase, which is the balance of a very great increase in the production of Sandur State and a nearly as great average decrease in that of the Vizagapatam district. Central India shows a great reduction in output, due to the working-out of the easily-won portions of the Kajlidongri deposit in Jhabua State; while the Mysore output was reduced by nearly one-half, owing to a similar result in the great Kumsi deposit in Shimoga district.

The bulk of the ore was shipped at Bombay, the other ports of shipment being, in order of importance, Mormugao, Calcutta and Vizagapatam. The heavy fall in the total exports for the year 1914-15 was due to the war, but there has since been a substantial recovery. (See Diagram 4, p. 42.)



The value, though not the amount, of the total exports during 1916-17 was greater than that of any preceding year. Exports to the United States reached their maximum in 1912-13, fell considerably in the following year, and in 1916-17 amounted to a little less than one-half of the average tonnage for the two years 1912-13 and 1913-14.

Exports of Indian manganese ore to Germany have never been large, that country having been the principal market for Russian ores. Exports to Belgium prior to the war were second only to those made to the United Kingdom, and a steady increase had been shown for several years. France and the United States came next in order of importance as buyers of Indian ore.

(In the table, values are expressed in pounds at the rate of 15 rupees to £1, this having been maintained since January, 1898, with but slight variation.)

Since 1892, there has always been an excess of production

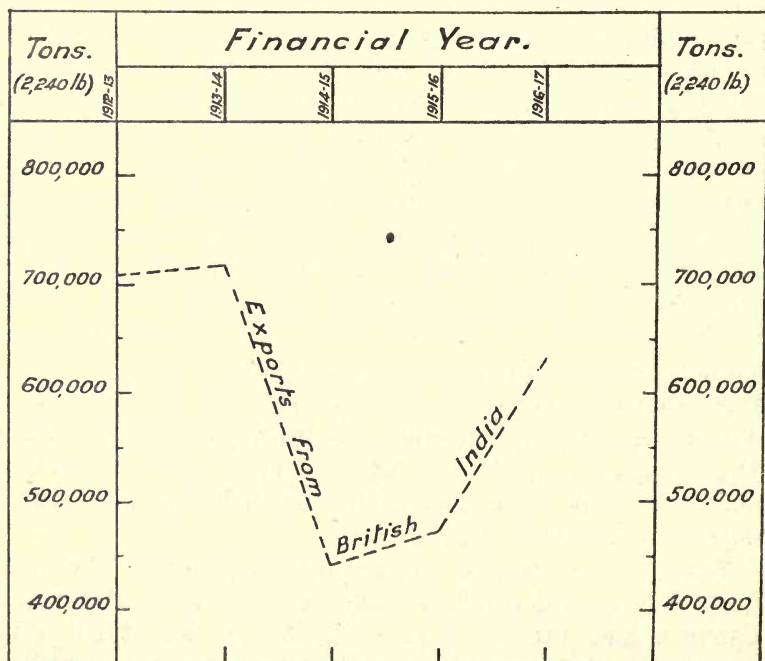


DIAGRAM 4.—EXPORTS OF MANGANESE ORE FROM BRITISH INDIA, APRIL 1, 1912—MARCH 31, 1917, SHOWING ADVERSE EFFECT OF WAR.

*Exports of Manganese Ore from British India* <sup>1</sup> (*April 1st, 1912–March 31st, 1917*)

(Long Tons.—Values f.o.b. at Indian ports)

To	1912-13.		1913-14.		1914-15.		1915-16.		1916-17. <sup>2</sup>	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
United Kingdom.	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£
Austria-Hungary	211,921	231,668	258,776	281,140	227,281	264,811	380,967	439,107	459,150	547,464
Belgium	3,300	3,960	10,310	12,372	4,030	4,836	—	—	—	—
France	171,066	184,287	187,821	212,308	66,043	72,396	—	—	—	—
Germany	112,223	128,244	103,847	127,648	46,326	56,231	20,000	23,150	61,940	75,926
Holland	7,250	9,060	18,950	23,952	14,250	17,908	—	—	—	—
Italy	23,850	27,935	8,200	8,700	—	—	—	—	—	—
Japan	6,600	7,920	7,800	9,360	—	—	20,850	25,812	28,400	36,595
United States	3,271	4,970	16,018	26,536	9,157	12,334	3,346	4,461	17,480	42,469
Egypt	168,600	164,654	106,327	106,747	73,503	73,503	47,400	61,376	63,912	127,294
China	—	—	—	—	—	—	—	—	200	266
	—	—	—	—	—	—	—	—	1	20
Total	708,081	762,698	718,049	808,763	440,590	502,019	472,563	553,906	631,083	830,033

<sup>1</sup> *Trade of British India (Tables) 1910-11 to 1915-16 (50th issue, Vol. I).*

<sup>2</sup> *The Indian Trade Journal, 1917, 45, 215*

of manganese ore in India over exports. Stocks of ore amounting to about 300,000 tons had been accumulated by the end of 1908, and these had been increased to rather more than 600,000 tons by the end of 1915 [21].

Omitting the figures for the period 1914-17 as being abnormal owing to the war, the percentages of the total quantity and value of the ore exported from India to the different purchasing countries during the first two years of the period covered by the above table work out as follows, the countries being grouped according to their attitudes during the first year of the war :

To	April 1st, 1912 — March 31st, 1914.	
	Quantity.	Value.
<i>Allied Countries :</i>	Percentage of Total.	Percentage of Total.
United Kingdom . . . .	33·07	32·63
Belgium . . . . .	25·16	25·24
France . . . . .	15·15	16·28
Italy . . . . .	1·01	1·10
Japan . . . . .	1·35	2·01
Total . . . . .	75·74	77·26
<i>Enemy Countries :</i>		
Austria-Hungary . . . .	0·94	1·04
Germany . . . . .	1·82	2·10
Total . . . . .	2·76	3·14
<i>Neutral Countries :</i>		
Holland . . . . .	2·23	2·33
United States . . . . .	19·27	17·27
Total . . . . .	21·50	19·60
Grand Total . . . .	100·00	100·00

*Comparative Cost of delivering Brazilian, Russian and Indian Manganese-Ore c.i.f. at London.*—The following comparative statement [22] must, of course, not be regarded as showing the actual cost of delivering manganese-ore at London at the present time, or, indeed, even immediately prior to the war ; but it nevertheless affords a useful criterion of the terms on which the leading producers have competed normally in the British market. (" Cost " includes Mining



and Administration, Royalty, Transport to and on Railway, Ocean Freight to London, Destination Charges, etc.)

	Brazil (Minas Geraes). <sup>1</sup>		Russia (Caucasus).		India.	
	At 1,000 milreis = 7 pence.	At 1,000 milreis = 14 pence.	According to Demaret <sup>2</sup> (1905).	According to Drake <sup>3</sup> (1898).	Central Provinces <i>vid</i> Bombay.	Vizagapatam.
	£ s. d. 1 10 8	£ s. d. 2 7 6	£ s. d. 1 15 5	£ s. d. 1 19 2	£ s. d. 1 16 4	£ s. d. 1 11 7
Price per unit at which the ore would be sold at no profit or loss.	d. 7·36	d. 11·4	d. 8·5	d. 9·4	d. 8·7	d. 8·2

<sup>1</sup> After Demaret, *Annales des mines de Belgique*, 1905, 10, 843.

<sup>2</sup> *Loc. cit.*, 886. <sup>3</sup> *Trans. Am. Inst. Min. Eng.*, 1898, 28, 207.

It will be seen that, with low rates of exchange, the Brazilian ores can, normally, compete on equal terms with those of India and Russia, but, with high rates, are at a considerable disadvantage. Comparing the Indian and Russian ores, it is seen that those of Vizagapatam cost less to deliver at London than the ores of the Central Provinces and Russia, the two latter costing about the same. Assuming the figures to represent the average cost fairly, also that all the ores are first grade, containing 50 per cent. of manganese, except the Vizagapatam ore, which is assumed to average 46 per cent. of manganese and fetches second-grade prices, then the last line in the table shows the price per unit at which the ore would be sold at neither profit nor loss. Since the Russian and Indian ores make up so very large a proportion of the world's total production, it follows that the price per unit of first grade ore can never fall below about  $8\frac{1}{2}d.$  to  $9d.$  without automatically so restricting production and export as quickly to send the price back to this level.

*Production of Ferro-Manganese in India.*—It has been urged by Fermor [23] that an enormous financial loss is caused to India by the export of its manganese ore in the raw condition, and that this could be avoided by converting the ore into ferro-manganese in India. At present, practically the whole of the Indian output of manganese ore is shipped to Europe

and America for conversion there, only a few thousand tons being used in India, and this chiefly as a desulphurizer in iron and steel furnaces. It is recognised, however, that countries in which furnaces have been set apart for the production of ferro-manganese would, if deprived of their Indian supplies of ore, endeavour to obtain their full requirements from Russia and elsewhere.

The demand for ferro-manganese in India itself probably does not exceed 2,000 tons a year [24] at present, although it is expected to increase somewhat in the near future. This, it is believed, could be supplied from India at a considerably lower figure than that for which the alloy can be imported. It is pointed out, however [24], that the high percentage of phosphorus not only in the Indian ore but also in the available Indian coke is a serious consideration, as the finished ferro-manganese would be likely to contain so excessive an amount of phosphorus as to cause a more expensive ferro to be preferred.

In discussing the project for the establishment in India of works for the production of ferro-manganese, it has been pointed out [25] that, while the cost of manganese-ore delivered in this country might represent about one-fifth mineral and four-fifths freight, in normal times the cost represented, say, two-thirds mineral and only one-third freight. For rough purposes, average shipments of manganese ore probably run close up to 50 per cent. of manganese; so that, allowing for a 25 per cent. loss in reduction, 2 tons of the manganese-ore will give about 1 ton of ferro-manganese. While this would afford the Indian producer an advantage over the home producer of half the freight, which normally runs between 15s. and 18s. per ton—that is to say, an advantage of about 8s. to 9s. per ton—it is argued that even this small advantage is more apparent than real, for the following reasons:

- (1) Manganese ore is carried as ballast, whereas ferro-manganese requires careful handling and packing.
- (2) Ferro-manganese oxidizes rapidly when exposed to the air, necessitating re-furnacing and consequent loss. In tropical heat, its stability will be still further impaired.

- (3) The ordinary methods of taring applied in this country would probably be ineffective, and more expensive methods required.

It is further pointed out that manganese ore is by no means exclusively employed for the production of ferro-manganese. In the basic process of steel manufacture, the ore is fed direct to the furnace; and, as this method is almost exclusively employed on the Continent, and will be more generally utilized in this country and in the United States after the war, we must look forward to an increased proportion going into consumption otherwise than as ferro-manganese. Even to-day the proportion is probably quite half.

It is also remarked that considerable quantities of manganese-ore are used in the chemical industry and the making of silica glass, for which the Caucasian ores are especially suitable, owing to the absence of iron. For the manufacture of ferro-manganese, the presence of a certain amount of iron is an advantage; but the manufacturer in Europe, especially in Great Britain, draws his ores from various sources, and can obtain very satisfactory results by mixing Caucasian and Brazilian ores and a certain proportion of, say, Carthagea manganiferous iron-ore, while, of course, the Indian manufacturer would be denied the advantage which comes from a wide range of ores for mixing. The article finally mentions the tendency of Indian manganese-ores to show an increasing percentage of phosphorus, and draws attention to the commercial competition which such an enterprise as ferro-manganese production in India would be bound to encounter, the difficulty of obtaining reasonable and regular freights for shipments to the United States, and the length of the voyage to that important market. It is suggested that the development of steel manufacture on a large scale in India is to be advocated, rather than the establishment of works for the manufacture of ferro-manganese for export.

A Commission appointed to report on the development of Indian resources generally has been investigating this question, and it is unlikely that any of the important considerations have escaped attention. The work of the Commission has now been suspended until after the war.



## AFRICA

EGYPT: *Sinai Peninsula*.—Discoveries of manganiferous deposits in the Sinai region were made by T. Barron, of the Geological Survey of Egypt, in 1898–99. These occurrences have been described in publications of the Survey [26]. It was demonstrated that the ore deposits situated in the southern half of West-Central Sinai, and more particularly those in the Um Bogma Hills, were suitable for commercial exploitation. The manner of occurrence of these ores has been summarized as follows [27]:

1. The ores occur invariably at the same geological horizon, namely, the base of the Carboniferous limestone series.

2. The ore-bodies consist of irregular deposits, with a tendency to assume the form of beds and lenticular masses.

3. The ore deposits are found only in the immediate neighbourhood of faults, and are thicker and richer in manganese at points close to the faults than elsewhere.

4. Wherever ores occur, the dolomitic limestones have partially or wholly disappeared, their place being taken by ochreous sandy clays and shales.

5. Where a part only of the limestone series has disappeared in the vicinity of ore deposits, it is always the lower part of the series which has vanished, the upper beds being left.

That the ore deposits are not true beds is evident from their discontinuous character and their rapid variations in thickness and composition. Although occurring at the base of the Carboniferous limestone, they are believed not to be of Carboniferous age, but to have been formed in late Tertiary times, and to owe their origin to solution of the dolomitic limestones by thermal waters coming up fault fissures, and concentration and oxidation of iron and manganese carbonates near the faults. Analyses have shown that the dolomites contain on an average 0.30 per cent.  $\text{MnO}_2$ , and are thus a possible source of the ore deposits.

Of the commercially valuable deposits in West-Central Sinai, those of special importance are situated in the Um Bogma Hills. These deposits, which are of considerable size, were discovered by Barron in 1898. After careful prospecting,

they have lately been considered worth working on a commercial scale. The ore consists of varying admixtures of oxides of iron and manganese, and is to be shipped to Europe for smelting.

Other localities in West-Central Sinai in which such deposits have been found are: Gebel Um Rinna; Wadi Kharig; Wadi Baba (near Bir Rekis); Wadi Nasib; around the heads of Wadi Abu Hamata and its tributaries; and in the neighbourhood of Bir Um Hamd.

In general, the presence of the ore band is clearly marked in the scarps by its dark colour, which enables it to be followed round for miles, but in some places the outcrop is covered with débris.

It is not proposed in this monograph to deal with the deposits in all the localities mentioned, but it will be useful to give some account of those of the Um Bogma district.

The principal deposits of this locality occur in four groups of hills, which for convenience of description have been named the Central, North, East and South Hills respectively.

A bed-like deposit of ore, averaging about two metres in thickness and measuring in places as much as four metres, extends through the greater portion of the mass of the Central Hills. Headings driven into the ore bed, from the two sides of the hill, show the ore to persist in a nearly horizontal sheet, with sandstones below and ochreous sandy clays above; the sandy clays are in turn overlain by yellow marls and crystalline dolomite. The ore is mostly of a rather soft character, varying from almost pure pyrolusite to an ochreous hæmatite, but there is also some psilomelane. As a rule, the deposits appear to be thickest and richest in manganese near the faces of the scarps, and to become more ferruginous farther in. This comparative richness at and near the scarp faces can be explained by proximity to faults, of which there are many, suggesting that faulting has had something to do with the genesis of the deposits.

The northern scarps of the East group of hills exhibit an almost continuous outcrop of ore at the usual horizon. The deposit appears to be continuous through the northern portion of the hills, the maximum thickness being near a fault, the

ore bed attaining a thickness of four metres, and containing numerous hard patches very rich in manganese, to the north of the Wadi Um Sakran.

The North Hills have not yet been so thoroughly prospected as the Central and East, but the ore deposits can be traced around almost continuously, and these hills probably contain deposits little if at all inferior to those of the Central group. The North Hills are intersected by at least three well-defined faults.

Highly ferruginous beds, with patches of hard and soft manganese ore, can be traced around a large portion of the South group of hills, and are likewise noticeable in the western part of the narrow ridge which connects the group with the Central Hills. Excavations made by prospectors have shown that the ore deposits here are thinner and poorer in manganese than those of the other groups of hills, while they do not appear to persist through the hill mass, but to be largely peripheral.

The mines, which are held under lease from the Egyptian Government, are situated about 15 miles south-east of the Abu Zenima, a place on the Gulf of Suez, 80 miles or thereabouts south-east of the town of Suez. The mining leases cover an area of about 510 acres, and certain Protection Areas and leases of land required for general purposes have also been granted.

The deposit has recently been described as a horizontal bed varying in thickness from a few inches up to 17 feet, with sandstone below and marl, dolomite and sandstone above, in the order named. The formation occurs on a plateau, 2,000 feet above sea-level, which, owing to erosion, has been dissected by deep ravines, along which it is possible in most cases to follow the ore yard by yard. The strata covering the bed have been partially, and in places wholly, eroded, so that the ore will be won either by open quarrying or by underground mining, according to the thickness of the overlying material.

It is estimated that, when shipping at the proposed rate, the grade of the ore could be maintained by selection at 35 per cent. manganese and 23 per cent. iron, and Engineers'



reports indicate that a limited quantity of ore averaging 47·2 per cent. manganese and 7·35 per cent. iron could be produced, if desired, without materially affecting the average-grade ore of the mines. The following analysis is stated to represent the average of 211 samples :

		Per cent.
Manganese	Mn . . . .	32·36
Iron	Fe . . . .	25·08
Silica	SiO <sub>2</sub> . . . .	2·79
Sulphate of barium	BaSO <sub>4</sub> . . . .	3·29
Phosphorus	P . . . .	0·126

More than 12,000,000 tons of ore are estimated to be available, of which nearly one-half has already been wholly or partially developed. Plant and transport arrangements have been designed for dealing with 300,000 tons of ore per annum, these including a narrow-gauge railway, 10 miles in length, from the port of Abu Zenima, and an aerial ropeway, 6 miles in length, from the terminus of the railway to the mines at Um Bogma. The pier, landing appliances and moorings at Abu Zenima will be suitable for ships not exceeding 10,000 tons burden. It had been anticipated that shipments of ore would commence before the end of 1914, but the outbreak of war caused a suspension of operations, and extensive damage was done by Turkish troops to the Company's buildings and plant at Abu Zenima, in February, 1915. The Sinai Peninsula was subsequently cleared of the enemy, and it was anticipated that the restoration and completion of the works at Abu Zenima would be effected by about the end of 1917.

Prior to the outbreak of war, a large proportion of the intended annual production had been disposed of to Continental smelters, who, it was understood, proposed using the product in connection with basic steel processes. The Egyptian Government (who now hold a considerable financial interest in the Company) have cancelled several of these contracts, and others are in abeyance if not entirely abrogated by war conditions; so that the whole of the Company's production is available for supply to English works, either as average-grade ore for use in the production of basic steel, or as selected ore for use in other processes. A first shipment

of manganese iron-ore to this country, made in October, 1918, amounted to 4,000 tons.

**SOUTH AFRICA: Cape Province.**—In a report [28] on the manganese deposits in the South-West Districts of the Cape Province, A. B. Welsh, Assistant Inspector, gives an account of deposits of manganese-ore investigated by him at Hout's Bay, Constantia Nek, Kogel Bay (in False Bay), Botha's Halt near Worcester, Du Toit's Kloof near Wellington, French Hoek and Caledon.

In a covering report, the Deputy Inspector of Mines points out that Cape ores are characterized by a comparatively low percentage of manganese and a relatively high proportion of phosphorus, the ores falling considerably short of the requirements necessary in the manufacture of ferro-manganese and spiegeleisen. The quantities of ore available are generally not large, the market for them is restricted, their average value is only about 30s. per ton, and costs of mining and transport are heavy.

The exceptional case as regards mining and sorting charges is the deposit at Caledon, which on that account is the most interesting, and the most likely to be exploited. This deposit is situated 2 or 3 miles from Caledon station, which is 87 miles by rail from Capetown. Unlike the other deposits, which are referred to as "lodes," the Caledon deposit occupies a kopje roughly circular in shape, with hot springs at the centre. Nearly the whole of the kopje consists of manganese-ore. In many places there is little or no overburden, and the ore could be worked by open quarrying.

The deposit covers an area of roughly 200 by 300 yards. On the top of the hill there are shafts and workings about 20 feet in depth and still in ore. The deposit thins out and becomes more siliceous as the outer margin of the kopje is approached. Assuming an average thickness of 10 feet, the available ore is estimated at about 500,000 tons. A sample of the best ore showed on analysis 37·87 per cent. of manganese, 16·3 of iron, 0·014 of sulphur, 0·378 of phosphorus and 6·55 of silica. An average sample was found to contain 25 per cent. of manganese and 30 per cent. of iron. It is pointed out that, although the excessively high content of phosphorus

would render it quite unsuitable for making spiegeleisen, the ore could be used for the manufacture of basic phosphoric iron. The quantity of ore required for that purpose, however, is not very great.

As difficulties standing in the way of exploitation, it is pointed out that a sanatorium and baths have been built on the deposit, and there is a possibility that mining would interfere with the working of the springs; whilst the distance from Capetown is a serious consideration.

Of the other deposits investigated, only two, namely those at Du Toit's Kloof and Hout's Bay, appeared to be of any considerable extent, so far as could be judged from surface indications and the development done. The following table compares these three occurrences roughly, according to their most important constituents, the figures being approximate:

	<i>Manganese.</i>		<i>Iron.</i>	<i>Silica.</i>	<i>Phosphorus.</i>
	Per cent.	Per cent.	Per cent.	Per cent.	
Caledon . . .	38	16-20	6.5	0.378	
Du Toit's Kloof . .	40	13-22	0.75-4	0.47-0.57	
Hout's Bay . . .	30	9-16	6.00-12	0.47-0.66	

The figures refer to clean hand-sorted ore. In every case, the total phosphorus is very high.

The Caledon deposit seems to be very much more extensive than either of the others, and the ore there can be quarried, whereas at the others vein mining will be required.

*Transvaal.*—Pyrolusite occurs in the form of veins in the neighbourhood of Pretoria, but the veins are small and the mineral is much mixed with gangue. A few tons per month are being mined in this locality, for use in the cyanide works of the Witwatersrand gold mines [29].

*Natal.*—Manganese ore occurs in Natal, and, although no output is included in statistics of the world's production, small shipments have occasionally been made.

A superficial deposit of manganese ore occurs in the bed of a stream on the farm Dwaalhoek, in the Vryheid district, near the Pivaan River. The underlying formation is described by F. H. Hatch [30] as consisting of quartzites, jasper-iron schists ("calico rock") and sericite schists belonging to the Barberton formation (Swaziland System), with traces of oxide



of manganese in the schists. The deposits of manganese ore, which consist chiefly of pyrolusite, together with wad and psilomelane, appear to have been produced by the leaching out of the oxide of manganese in the schists, this becoming locally concentrated, together with limonite, in a surface deposit in which fragments of shale and quartzite are cemented to a breccia. The deposit has a length of 75 feet, with a maximum width of 15 feet. A shaft, sunk to the east to a depth of 75 feet, in the hope of striking its downward extension, passed through shales containing only traces of manganese, finally reaching quartzites. A sample, taken by Hatch from a dump of about 10 tons of ore extracted from this deposit, contained 26.21 per cent. of manganese, 24.13 of iron, 11.26 of silica, and 0.025 of phosphorus, showing the mineral to be a low-grade ferruginous manganese ore, which could not be profitably mined.

Another area examined by Hatch, on the farm Goedegeloof, Nyalisa, some 50 miles from the railhead at Hlobane, showed shales of the Barberton formation locally and superficially impregnated with manganese-ore. The workings were confined to an area about 250 feet in length by 150 feet in width, and consisted of pits and cuttings in the shale, at the foot of a quartzite hill, in comparatively flat country. The formation consists of red sandy shales impregnated with small seams and nodules of manganese-ore (psilomelane, wad and pyrolusite), together with a small quantity of rhodonite. One shaft had been sunk to a depth of 20 feet, and showed that the manganese impregnation extends to a depth of only 17 feet, the manganese ore constituting roughly 10 per cent. of the whole material intersected to that depth. A bulk sample of hand-picked material contained 33.41 per cent. of manganese; 12.45 per cent. of iron; 16.66 per cent. of silica; and 0.051 per cent. of phosphorus. A sample of more closely picked ore shipped to England is reported to have contained 48.18 per cent. of manganese; 4.9 per cent. of iron; 7.6 per cent. of silica; and 0.046 per cent. of phosphorus. Even on this analysis, the ore can only be regarded as second class, although its silica and phosphorus contents are so low.

Other deposits, of a similar nature, occur in the district, as at Bellevue and Kruisfontein, and at Baviaan's Kranz, on the Pivaan, near its confluence with the Pongola River. It would appear that these deposits are not of sufficient size, and the ore is not of sufficient purity, to allow of profitable working.

The manganese ores of Natal, even when most carefully hand-picked, cannot be brought up to a 50 per cent. manganese grade, and in view of this fact, as well as of the high cost of working material of their character and the heavy transport and freight charges that shipments would have to pay, Hatch concluded that the idea of establishing a manganese industry in the Colony was impracticable.

*Rhodesia*.—So far as is at present known, ores of manganese are very sparsely distributed throughout Rhodesia. Lateritic manganese ore occurs in the neighbourhood of the Somabula diamond workings, but not apparently in considerable quantity [31].

ST. HELENA.—It was officially stated, in 1905 [32], that prospecting during the year had resulted in the discovery of large deposits of manganese ore of good quality. Samples investigated at the Imperial Institute showed that the mineral would require concentration before shipment. The deposits occur on the eastern side of the island, at an altitude of from 1,000 to 1,500 feet, and ore therefrom could be placed on board ships anchored quite close to the works. In an authoritative report made in 1906, it was stated that, by reason of the poor quality and small quantity of the mineral contained therein, the deposits, which were described as occurring in decomposed lavas, possessed no value.

WEST AFRICA: *Gold Coast*.—In his report for 1914, the Government Geologist described a promising discovery of manganese-ore on the eastern side of the Taquah Banket Range, at Dagwin, in the Wassaw district. The deposit occurs on the Dagwin Extension claims belonging to the Wassaw Exploring Syndicate, an undertaking controlled by the Fanti Consolidated Mines, Ltd., and is situated within about 200 yards of the Gold Coast Government Railway;

which gives direct access to the seaport of Sekondi, some 33 miles distant. An analysis made at the Imperial Institute showed a sample of the ore to contain the equivalent of 56 per cent. of metallic manganese. The deposit is at the present time being worked by the Fanti Consolidated Mines.

S. H. Ford [33] has recently given an account of the deposits at Dagwin, from which the following information is derived. Massive outcrops are found on the crest of a ridge which runs north-east for about  $2\frac{1}{2}$  miles from the 33-mile post on the Sekondi-Kumasi Railway. A preliminary examination showed that the outcrop is practically continuous over the whole  $2\frac{1}{2}$  miles, and that, generally, it consists of ore with from 42 per cent. to 52 or 53 per cent. of manganese. There are, however, patches where the manganese content is so low that the material is valueless. Similar ore has been found still farther to the north-east of this district.

The ore shipped so far has been recovered from a detrital deposit lying on the slopes of the main ridge, which is the result of the weathering of the main outcrop on the crest. The detritus consists of boulders and nodules of ore embedded in clay, and the thickness of the surface deposit varies from 18 inches to 15 feet. The method of winning the ore is to uncover the boulders and larger fragments by pick and shovel work, along a line parallel with the length of the ridge, commencing at the lowest possible points on the slope, and working upward. The effect of this is to remove a slice from the whole of the surface of the hill slope, the thickness of the slice corresponding with the depth of the deposit. The overburden and clay, with any ore which is obviously too high in iron to ship, are thrown behind the labourers on to the lower slopes of the hill, while the embedded nodules, and the boulders, after blasting, are stacked for sampling, and assayed before being trammed to the siding for despatch by rail. The question of the treatment of the clay with nodules of ore is under consideration.

According to the same authority, the mineral generally is psilomelane, although occasionally pieces of pyrolusite are found. Broadly speaking, the amount of manganese plus iron is fairly constant at 55 or 56 per cent. ; thus, with 53



per cent. of manganese, there is about 3 per cent. of iron ; while, in clean ore, the silica and phosphorus are low. Up to July 31st, 1917, 20,600 tons had been shipped, with an average content of 52 per cent. of manganese, 4·6 per cent. of iron, 4 per cent. of silica, and 0·11 per cent. of phosphorus. The total shipments to June 30th, 1918, amounted to 42,474 tons.

It is pointed out that, although the distance from the port is only 33½ miles, the freight charge over the Government railway is 6s. per ton, with 1s. per ton harbour dues, and that this includes no handling whatever. The handicap of this very high rate will be realized when it is mentioned that it is about ten times as high as the rate on manganese-ore delivered at Bombay over the Indian railways. Shipments for the first half of 1918 averaged only 1,321 tons per month, as against 2,523 tons per month in 1917.

Other high-grade manganese ore has been discovered in the neighbourhood, and it is expected that as soon as railway facilities have been provided, the output of ore will be considerably increased.

BRITISH EAST AFRICA.—Three samples of manganese-ore from a deposit in the East Africa Protectorate were examined at the Imperial Institute in 1909. These were understood to have come from deposits in a sandstone formation covering a considerable area, the precise locality of which was not disclosed. The samples consisted of massive manganese-ore containing varying amounts of granular quartz impurity. One sample contained so large a percentage of silica as to render it, on that account alone, of no commercial value. Analyses of the other two samples gave the following results, showing that each represented material of value as manganese-ore, although the percentage of silica is undesirably high :

		No. 1. Per cent.	No. 2. Per cent.
Manganese dioxide	MnO <sub>2</sub>	66·91	66·24
Manganous oxide	MnO	4·75	5·61
Ferric oxide	Fe <sub>2</sub> O <sub>3</sub>	1·80	0·43
Silica	SiO <sub>2</sub>	13·85	11·37

		No. 1. Per cent.	No. 2. Per cent.
Alumina	$\text{Al}_2\text{O}_3$	7.58	6.07
Lime	$\text{CaO}$	0.56	0.22
Baryta	$\text{BaO}$	2.35	3.78
Phosphorus pentoxide	$\text{P}_2\text{O}_5$	0.07	trace

In both cases the percentage of phosphorus was satisfactorily low.

### NORTH AMERICA

CANADA.—Ores of manganese have been mined in the Provinces of Nova Scotia and New Brunswick since 1864, the mineral being notable for its purity, high manganese content, and low phosphorus. Between 1880 and 1890, shipments of high-grade pyrolusite averaged 1,500 tons annually, the mineral of the deposits worked during that period occurring in rich aggregates of very pure ore, the individual pockets, however, being of limited extent, rendering mining difficult. The production during the present century has been quite unimportant, being only 25 long tons in 1914, 179 tons in 1915, 874 tons in 1916, and 180 tons in 1917. The domestic consumption of high-grade pyrolusite is less than 20 tons a year, and consequently the home market has hitherto offered little inducement for active development of domestic resources. Indeed, some 1,300 tons of mineral of lower grade is imported annually, the bulk of which is used in the dry battery, glass and varnish industries. For the first-mentioned purpose, the specification in England is 86 per cent. manganese dioxide, and not exceeding 1 per cent. iron; and, as much of the Canadian mineral complies with these requirements, there appears to be no reason, other than temporary lack of good transport facilities, why imports of lower-grade mineral should not be superseded by high-grade Canadian material in the chemical industries mentioned.

*British Columbia.*—A deposit of manganese ore, which appears to have considerable prospective value, is now being developed in a locality about  $6\frac{1}{2}$  miles from Kaslo, in this Province, the property lying on a hillside immediately above the Kaslo and Nakusp Railway. A few shallow pits have

shown that the ore occurs on the surface or a few feet below, forming a layer from 1 to  $3\frac{1}{2}$  feet in thickness in the soil. So far the deposit has not been found to be closely associated with or bounded by any rock in-place. The ore, being principally wad, can be extracted by pick and shovel. The thin layer of soil covering the deposit also contains manganese in varying quantities. It was estimated in 1917 that from 3,000 to 5,000 tons of ore were ready for extraction, averaging 42.06 per cent. manganese; 1 per cent. iron; 4 per cent. silica; 0.01 per cent. phosphorus; and 13.12 per cent. moisture; and it was anticipated that further development would expose a considerable further tonnage of ore. Farther down the hill and almost at the same level as the railway track, in some small exposures, manganese ore has been found to occur underlying a layer of soft decomposed limestone, which has been eroded away farther up the hill, leaving the ore exposed on the surface [34].<sup>1</sup>

*Nova Scotia* [35].—The most important manganese-bearing section is that near New Ross, Lunenburg County, from which the whole of the small production for 1917 was derived. Two mines are being operated in this district, and two well-defined lodes have been worked, carrying extremely pure pyrolusite, with a little manganite and psilomelane. Some iron oxide occurs on one wall, but this is easily separated. The New Ross pyrolusite contains about 58 per cent. metallic manganese ( $MnO$  averaging from 85 to 90 per cent.), and this degree of purity is about the average of Canadian manganese-ores. The ore shipped by the Rossville Manganese Company, Ltd., from which 179 tons were produced in the year ended September 30th, 1917, has averaged 92 per cent. manganese dioxide and less than 2 per cent. iron [36]. The lodes of New Ross occur in a biotite granite, the width of the vein in what is known as the New mine varying from 1 inch up to 6 feet. A sorting and washing plant has been installed to prepare the ore for market, air separation being used for

<sup>1</sup> Deposits of manganese ore have recently been discovered on Vancouver Island, B.C., in a belt of rock extending from Mount Sicker to Cowichan Lake, a distance of about 40 miles, the majority of the samples showing over 40 per cent. of manganese. Assays show a high content of silica, but phosphorus is quite low. Development is proceeding.



the finer grades. The existence of an important ore-body has been proved, but work has ceased, owing largely to the distance over which the mineral has to be hauled (about 50 miles) to the nearest shipping point, and the lack of a good road.

At the Tenny Cape Mines, in Hants County, where the most important deposits of manganese ore in Nova Scotia occur, high-grade fibrous pyrolusite is associated with psilomelane, manganite also being met with in small quantities. The ore occurs in flat nodules, seams and lenticular pockets, the seams varying in thickness from 1 to 6 inches, and the pockets from 1 inch to several feet, some of the latter being said to have produced as much as 1,000 tons of ore. The deposits occur along an outcrop of dolomitic limestone associated with a layer of red shales, which dips steeply and is generally less than 300 feet in thickness. This layer (which is underlain by a massive sandstone of Devonian age) is much brecciated, and the ore is found in the brecciated portions, between the fragments and surrounding them, and in the large solid masses along bedding planes and cross fractures [37]. The ore of the Tenny Cape mine, proper, is said to carry from 88 to 95 per cent. of manganese dioxide, and to be free from deleterious elements. The mine is not now worked, but it is stated that considerable ore is still available for extraction.

There was no output of manganese ore in Nova Scotia in 1914-15, or in 1918, but 544 tons were produced in 1916, and 180 tons in 1917.

*New Brunswick.*—Manganese deposits occur throughout the southern part of this Province, in the area underlain by Carboniferous limestone. The most important deposit occurs at Markhamville, near Sussex, King's County, where the ore is described [38] as crystalline pyrolusite and manganite, with small amounts of psilomelane in some places, the deposits being in the form of irregular pockets, or in flat lenticular layers generally following the bedding planes of the limestone. The Markhamville mine has produced some ore of the highest grade known, much of the pyrolusite containing from 96½ to 98¾ per cent. of manganese dioxide, with only one-half of 1 per cent. silica and three-fourths of 1 per cent. iron [39].

The large amount of available oxygen and the freedom from impurities have caused it to be highly prized by glass-makers. The manganite with which it is associated is said also to be of high grade and to have been used for steel manufacture.

Among smaller deposits of manganese-ore in New Brunswick is that discovered at Jordan Mountain, 17 miles from Markhamville, where the ore occurs near the contact of the lower Carboniferous sediments with pre-Cambrian crystalline rocks (gneiss and felsite). The deposit is a lens conformable with the bedding of the enclosing strata, the mineral consisting of fine-grained and massive pyrolusite mixed with manganite. Analyses of ore from the Jordan Mountain deposit have been reported as follows :

		No. 1. Per cent.	No. 2. Per cent.
Manganese dioxide	MnO <sub>2</sub> .	86.08	—
Metallic manganese	Mn .	54.57	57.37
Silica	SiO <sub>2</sub> .	2.86	0.23
Phosphorus	P .	—	0.15
Sulphur	S .	—	0.61
Iron oxide	Fe <sub>2</sub> O <sub>3</sub> .	0.87	—

One of the more important deposits of manganese-ore in New Brunswick occurs at Dawson Settlement, about 5 miles west of Hillsborough in Albert County and 1½ mile from the Salisbury and Albert Railway [40].

The ore has been deposited as a form of sinter surrounding some springs which issue from the hillside. The deposits vary from 150 to 500 feet in diameter, and are thickest (26 feet) close to the springs, becoming thinner as the edges of the ore masses are approached. The amount of ore present in these deposits has been estimated to be about 170,000 tons. When this deposit was worked some years ago, it was found necessary to briquette the manganese ore on account of its soft and crumbly nature. Mining operations, however, were not continued for long, and no further development of this deposit has been recorded.

*Quebec.*—A spathic iron-ore rich in manganese occurs in the Nestapoca chain of islands, an average sample from Flint

Island yielding 25 per cent. of iron and 24 per cent. of manganese carbonate. These deposits are easily accessible, and may permit of profitable working. It is advantageous, where suitable fuel is cheaply available, to roast such ores before shipment, having regard to freights.

Deposits of manganite, said to be of considerable size, occur on Amherst Island, one of the Magdalen group, and some exploratory work has been done.

*Alberta.*—Deposits of low-grade manganiferous material are reported to occur in the Cypress Hills, but according to the Canadian Geological Survey [41] these contain on an average only about 5 per cent. of manganese, and appear to be of little or no value.

The following are some analyses of Canadian manganese ores :

—	Percentage of					Nature of Ore.
	MnO <sub>2</sub> .	Mn (total).	Fe <sub>2</sub> O <sub>3</sub> .	SiO <sub>2</sub> .	P.	
<i>Cape Breton Co. :</i>						
Morrison Mine, Loch Lo-						
mond . . . . .	91.84	—	0.12	2.91 <sup>1</sup>	—	Pyrolusite.
Boularderie Island . .	44.33	—	35.50	10.00 <sup>1</sup>	—	Wad.
<i>Colchester Co. :</i>						
Londonderry . . . .	67.10	—	—	4.08	—	—
<i>Hants Co. :</i>						
Tenny Cape . . . . .	85.54	—	1.18	3.27 <sup>1</sup>	0.34	—
Cheverie . . . . .	90.15	56.97	2.55	2.80 <sup>1</sup>	0.45	Pyrolusite.
<i>Pictou Co. :</i>						
Springville . . . . .	14.41	9.10	48.22	—	0.02	—
<i>Albert Co. :</i>						
Dawson Settlement . .	—	45.81	13.65	5.36	0.05	—
<i>King's Co. :</i>						
Markhamville . . . .	97.25	—	0.85	—	—	Pyrolusite.
<i>St. John's Co. :</i>						
Quaco Head . . . . .	71.54	58.20	2.19	8.37 <sup>1</sup>	0.02	Pyrolusite.

<sup>1</sup> Silica and insoluble matter.

NEWFOUNDLAND.—Extensive deposits of low-grade manganese ore have been reported to occur along the south side of Conception Bay, in conjunction with limestone, near the base of the Cambrian series [42]. N. C. Dale states that



there are occurrences at Manuels, Topsail, Long Pond, Chapel Cove and Brigus within 10 miles of each other on Conception Bay [43], other occurrences are found some 50 miles to the north-west on Smith Sound in Trinity Bay, and occurrences are reported also some 50 miles to the south-west on Placentia Bay. There is a good exposure in Manuels Brook, where the ore consists of a nodular deposit of complex manganiferous carbonate. Various attempts have been made to work the deposits, but no regular mining appears as yet to have been done. A sample of manganese-ore from Conception Bay examined at the Imperial Institute was shown by analysis to consist of impure manganite, containing 38·0 per cent. of manganese, 17·56 of silica, 2·00 of iron, and 0·100 of phosphorus.

WEST INDIES: *Jamaica*.—Pyrolusite occurs at Marshall's Hall, in the parish of Portland, County of Surrey. It has been briefly described by J. G. Sawkins [44] as occurring in the Lower Tertiary Conglomerate Series, near an intrusive dyke. The quantity is said to be moderate, but the mineral commanded a price of £8 per ton in England at the date of his report (1869). No mining operations had been undertaken. Referring probably to the same deposit, L. Barrett [45] reports the occurrence on the west bank of the Dry River (Marshall's Hall) of large blocks of pyrolusite embedded in porphyry, quantities being scattered over the surface and in the streams. No excavations had been made, and consequently the mode of occurrence of the mineral had not been ascertained. It existed in considerable quantities, and he believed that it might be worked with profit if it were not situated at so great a distance from the coast. (The direct distance from the nearest point of the coast appears to be only about 10 miles.) Barrett mentions also manganite as occurring in a very interesting manner on the banks of the Guava River in the same parish, where many small veins could be seen in the process of formation. Numerous fissures are stated to cross the bed of the river through which issued jets of hot water having a temperature of 132° F. The sides of these openings were lined with crystals of calcite, enclosing a central rib of manganite, presenting the appearance of a small mineral vein. In some places the fissures were com-

pletely closed by these minerals, but at others the thermal water still issued. Sawkins (*loc. cit.*) mentions the occurrence at Boston of a deposit of manganese ore associated with a large proportion of oxide of iron, of which he made no analysis. Near this deposit were larger ones consisting of iron oxides.

*St. Thomas Island.*—In 1896, it was reported that a deposit of manganese-ore of good quality and considerable extent had been found on this West Indian island ; but no ore appears to have been exported.

### AUSTRALASIA

*New South Wales.*—Ores of manganese occur in considerable quantity in different localities and formations, but the deposits are situated at such distances from the coast that the cost of land-transport added to freight to Europe has hitherto prevented exploitation. The question of the extent and character of the manganese-ore deposits, not only of New South Wales, but of all the States of the Commonwealth, will become of more serious importance with the development of the iron and steel industry in Australia. The domestic supply of manganese ore will almost certainly be ample for the requirements of that industry, even if it should assume large dimensions. The output in 1915 was 713 tons, valued at £535, and, in 1916, 1,924 tons, valued at £1,443, the whole of the production in both years being obtained from deposits at Grenfell. The total recorded output of manganese ore up to the end of 1916 amounted to only 3,213 tons, valued at £3,640.

*Queensland.*—This is one of the more important parts of Australia, at the present time, as regards production of manganese-ore. The output has hitherto been small, amounting to 4,600 tons in 1902, but averaging only a little over 1,000 tons a year for the period 1903–11. The production in later years has been as follows: 1912, 308 tons; 1913, 27 tons; 1914, 6 tons; 1915, 200 tons; 1916, 643 tons (valued at £2,793); and 1917, 21 tons (valued at £105). The output is taken by the Mount Morgan gold mine, and utilized for the chlorination process,

The Queensland ore has been obtained chiefly, and in recent years entirely, from the Gladstone district, where it occurs in ferruginous slates, schists, quartzites and other altered sedimentary rocks intersected by igneous dykes and supposed to be of Permo-carboniferous age. The deposits are sometimes lenticular, their longer axes parallel with the cleavage of the rocks, running from north to south; but in general they are irregular in shape and occurrence. The Gladstone manganese ore area is roughly 15 miles in length by 12 miles in greatest width. The outlet for ore is by the Calliope River to Rockhampton, to which place there is also railway communication. Most of the country within the manganese area is less than 100 feet above sea-level, the highest hills being not much over 500 feet in altitude.

The most important producing mine in the Gladstone district is the Mount Miller, the workings of which are situated in a hill rising 400 feet above the Calliope River. The ore-body here is extremely irregular in strike, dip and thickness, the width of clean ore varying from 3 feet up to 21 feet. The ore consists chiefly of psilomelane, but it contains also pyrolusite and probably braunite. It is massive, and mostly steel-grey, silica and country rock being the chief impurities. The output from the Mount Miller mine from May, 1895, to the end of 1903 was 5,553 tons, of which 1,350 tons mined in 1903 averaged 74·1 per cent. of manganese dioxide. The average annual production was approximately 1,000 tons down to 1911, since which it has dwindled.

In his Report for 1914, the Assistant Government Geologist remarks on the comparatively high manganese percentage of the ore in the deeper levels of the Mount Miller mine. Although the ore averages nearly 20 per cent. of silica, he thinks that, in times of acute shortage, it might be valuable as a substitute in certain industries other than that for which it is now mined. At the date of his Report, 35,350 tons of ore containing from 18 to 51 per cent. of manganese were developed in the Mount Miller mine, but only a few hundred tons of first-grade shipping ore had been exposed.

Deposits have also been worked in the same district at Auckland Hill, occasional small shipments having been made



from the mine of that name since 1895, the ore averaging about 65 per cent. manganese dioxide.

Several manganese ore deposits have been worked from time to time in the Rockhampton district, between that town and Emu Park, to supply the Mount Morgan gold mine. The main workings in this district are at Coorooman, where the ore produced contains from 60 to 70 per cent. of manganese dioxide. The output of the district has never been large.

Deposits occur also in the Maryborough, Ipswich and Darling Downs districts, but there has hitherto been no production worth recording from these localities. In the Ipswich district, a mangiferous outcrop extends over an area of 6 square miles.

Near Gympie, during 1914-15, attention was given to the manganese-ore occurrences of Pie and Eel Creeks, where a certain amount of prospecting was done and several hundreds of tons of ore were mined. Further prospecting in this area would probably disclose other deposits [46].

*South Australia.*—The mining of manganese ore in this State began in 1882, when 131 tons were produced. Between that date and 1895, production was recorded every year, the highest output being 2,764 tons in 1890. Between 1895 and 1914, only 160 tons were raised. The industry appears again to be attracting some attention, 250 tons, value £563, having been produced in 1915, while the value of the output for 1916 has been returned as £2,700 [47-2], the tonnage not being stated.

Deposits of manganese ore at Pernatty Lagoon attracted attention in 1916 [47-1], the main group of leases and claims being situated about 4 miles north-east of the "71 mile," or Woocalla, on the Port Augusta to Kalgoorlie Railway. The ore occurs as pockets in dolomite and the overlying soil. Analyses of twelve samples show percentages of metallic manganese ranging from about 45 to 56, and percentages of peroxide ranging from about 65 to 89. In eight of the samples the phosphorus percentage is less than 0.01, and the highest recorded for the twelve samples is 0.09. The sulphur percentage ranges from 0.09 to 0.58.

The deposits consist in part of mangiferous iron-ore, a

sample of which showed 27·67 per cent. of manganese, 34·04 of iron, 0·13 of phosphorus and 0·13 of sulphur.

There is an overburden averaging as a rule less than 2 feet in thickness. It is estimated that in mining operations from 1 to 2 tons of waste are removed per ton of good ore, but, if a market could be found for the manganiferous iron ore, there would be less waste.

A feature of special interest is the presence in the deposits of material containing over 89 per cent. of manganese peroxide.

The deposits at Pernatty Lagoon are being worked by the Australian Manganese Company, whose agents have reported that a shipment of 117 tons made recently to Liverpool assayed over 85 per cent. of manganese dioxide and under 3 per cent. of iron. Operations have been hampered by shortage of water and lack of carters from the mine to the nearest railway station, but it is now expected that a monthly output of 400 tons can be maintained.

*Tasmania.*—Deposits of manganese ore are reported to occur at Zeehan, in the west of the island, but no production has been recorded.

*Victoria.*—Both manganese ore and manganiferous iron ore occur in large masses in Eastern Gippsland, but there is practically no production. The output of manganese ore for 1915 amounted to only 97 tons, value £337, and in 1916 to only 85 tons, value £300; while the total production of the State to the end of 1916 has been only 247 tons, value £919. The output is obtained from deposits at Heathcote, Bendigo District.

*New Zealand.*—Manganese ore has been found in fair quantity in the North and South Islands, the more notable deposits occurring at Tikiora, near the Bay of Islands; Waiheke Island, in the Hauraki Gulf; Paraparaumu, about 30 miles north of Wellington, and Taieri Beach, Otago [48]. The Otago ore shows over 90 per cent. of manganese dioxide. There is no home market for manganese ore, and, notwithstanding the offer of a bonus for the manufacture within the Dominion and export to a foreign market of spiegeleisen or manganese-bronze, there has been practically no production

since 1907. From 1878-1907, over 19,000 tons of manganese ore, value £61,000, were exported.

It is officially recognized that, even at the unusually high prices current in 1917, the shipment of manganese-ore from New Zealand to the northern hemisphere is hardly commercially possible until ocean freights and insurance are considerably reduced.



## CHAPTER III

### SOURCES OF SUPPLY OF MANGANESE ORES (*continued*)

#### (b) FOREIGN COUNTRIES

##### EUROPE

AUSTRIA-HUNGARY (including *Bosnia* and *Herzegovina*).—The production of manganese ore in Austria-Hungary has never been conducted on a large scale, and the output for the years 1911-13 showed a considerable falling-off as compared with that for the previous decade, the annual average for the three years in question being only 15,000 metric tons for Austria-Hungary, while that for Bosnia-Herzegovina was 4,316 tons. Later statistics are not available for Austria, but for 1914 the production of manganese ore in Hungary was 11,413 metric tons, and in Bosnia-Herzegovina 4,120 tons. It would appear certain that the output of manganese-ore from the well-known deposits must have appreciably increased since extraneous supplies were cut off by the war. The ore is generally of low grade.

The chief producing centres are the Bukovina and Krain, and these, while of comparatively small importance in normal times, must have been of considerable value to Austrian steel-works during the war.

A description of the geology and occurrence of the manganese ore deposits of the Drona Vatra district, in the Bukovina, and the methods of working adopted, was furnished recently by H. K. Scott [49]. From this it would appear that the deposits in the Bukovina, while not of high grade, are richer than any continuously worked in the Austrian Empire or in Germany. They occur in the neighbourhood of Jacobeni, in the south-west of the Bukovina, near the Roumanian and Hungarian frontiers, and have been known for three-quarters of a century, although originally worked for their iron content.

In 1902, Jacobeni was connected by a branch railway with the main line from Bucharest to Lemberg, Cracow and Vienna, and the output of manganese-ores was consequently increased. The ore occurs in lenses, consisting of both oxide and carbonate, the average assay being 33 per cent. of manganese, with phosphorus present. The richer ore is separated by hand-picking, the remainder being crushed and concentrated by jigging. The lenses of ore already developed guarantee an annual output of 50,000 tons for three years, while further quantities will doubtless be proved at lower levels. Before the war, the Witkowitz Company, in Austrian Silesia, was a large buyer of the concentrate for ferro-manganese production, while the hand-picked ore was bought by glass- and chemical-makers. Schemes were in hand for more extensive development of the mines.

Deposits of manganese-ore occur also in Carniola, Bohemia, Istria, Styria and other parts of the former Empire.

**BELGIUM.**—There has been no production of manganese ore in Belgium since 1909. The highest annual output recorded since the beginning of the present century was 14,440 metric tons, the average annual output for the period 1900-9 being about 5,600 tons. Manganiferous iron ores are mined chiefly in the Province of Liège. Of the total quantity of manganese ore exported from India during the two years from April 1st, 1912, to March 31st, 1914, the proportion received by Belgium was 25·16 per cent., the figures for 1912-13 being 171,066 long tons, value £184,287, and, for 1913-14, 187,821 tons, value £212,308, Belgium being, next to Great Britain, the largest buyer of the Indian ore.

Belgium has also been a large purchaser of Russian manganese-ore, her imports in recent years having been as follows : 1912, 193,500 tons ; 1913, 182,500 tons ; 1914, 154,467 tons. The Russian exports to Belgium in the first two of these years represented 19·15 per cent. of the total tonnage exported. The large reduction in 1914 was, of course, due to the war. Of recent exports of manganese ore from Brazil, Belgium received the following quantities : in 1911, 34,840 tons ; 1912, 10,900 ; 1913, 11,800. In 1914, 10,600 tons of Brazilian ore had been received before the war started. Belgium was

third in order of importance as a purchaser of Brazilian ore, the United States ranking first, and Great Britain second.

BULGARIA.—The Bela manganese ore deposit is situated about  $7\frac{1}{2}$  miles south of Varna, near the Black Sea, occurring in strata of Tertiary age consisting of clays approximating in places to a sandstone. The ore is described [50] as wad, occurring in lenses varying in thickness from  $\frac{1}{2}$  in. to 6 in. or more, over a width of 10 feet to 20 feet of the clay, the deposit containing a large quantity of mineral with 35 per cent. of manganese in the dried ore. This cannot be shipped at a profit in the raw state, but might be profitably handled if the ore were sintered or briquetted. The percentage of phosphorus is high, that of manganese low, while in its raw state the ore contains upwards of 20 per cent. of moisture, and on exposure to the atmosphere disintegrates, passing into a physical condition undesirable for blast-furnace use.

Manganese ore also outcrops at Dobra Nadejda, 2 miles from the station of Jambouli, pyrolusite occurring in beds from 1 to 4 feet in thickness, with an andesite foot-wall and a limestone hanging-wall. The ore is of low grade.

FRANCE.—The domestic production of manganese ore in France has never been of important size, and heavy imports have been required.

Recent figures for imports are as follows: 1911, 235,400 metric tons; 1912, 225,379 metric tons; 1913, 258,929 metric tons. Complete statistics are not available for imports in 1914; but, of the quantity received, 103,847 tons came from India and only 23,951 tons (or about half the normal quantity) from the Caucasus. The imports from India in 1915 were on a much-reduced scale, owing to the war and the requirements of Great Britain.

The production of manganese ore in France in 1913 was 7,732 metric tons. Later statistics are not available.

The chief occurrences of manganese ore are at the Las Cabesses mine, Department of Ariège (Pyrenees), and the Romanèche and Grand Filon mines, Department of Saône et Loire. The Las Cabesses mine formerly produced considerable quantities of carbonate ore, which occurred there as a mass about 200 feet in length and 165 feet in width.



This had been opened to a depth of about 230 feet by the year 1893. Such of the carbonate ore as was sold raw contained an average of 40 per cent. of manganese, 5·9 per cent. of silica, and 0·048 per cent. of phosphorus. Calcining in kilns brought up the content of manganese to 54·3 per cent., increased the silica to 9·3 per cent., and reduced the phosphorus to 0·041 per cent., the calcined product showing a loss in weight of about 32 per cent. on an average for the year 1893. The mine ceased work in 1904, since when the chief producers have been the Romanèche and Grand Filon mines, which yield pyrolusite.

GERMANY.—Almost the entire German production of manganese ore has been obtained from the neighbourhood of Coblenz, the principal mines being the consolidated Schlossberg, Amalienshöhe, Concordia and Elisenhöhe. The ore occurs usually in pockets. There are also a number of maniferous iron ore deposits, in the region of Siegen and Nassau, the mineral from which is largely used for the making of spiegeleisen. In 1911, the total production of these deposits was over 3,000,000 tons, of which, however, only an insignificant proportion contained 30 per cent. of manganese, while only about one-tenth had a content exceeding 20 per cent., the remainder assaying as low as from 2 to 12 per cent. In 1912, there was an output of low-grade ores, mainly from the Bonn district of Prussia, amounting to 92,474 metric tons, the production in 1913 being 330,797 tons, an increase which may be not without sinister significance.

The only deposit producing before the war what is commercially considered as manganese ore was that at Giessen, and the output from this source was only a few hundred tons [51]. Imports of foreign manganese ores into Germany rose from 223,709 tons in 1903 to 523,132 tons in 1912, about 64 per cent. of the tonnage in 1912 coming from Russia, about 24 per cent. from India, about 6 per cent. from Spain, and about 4 per cent. from Brazil. In 1913 [52], the total imports of manganese ore were 680,371 tons.

The cutting-off of foreign supplies at the outbreak of the war rendered it necessary to exploit more rigorously the domestic sources of manganese ore suitable for ferro-manganese

production ; but, having regard to the abnormally high imports of Russian and Indian ores in 1913, also to the invasion of Belgium and Northern France and the seizure of the large ore-stocks of those regions, as well as to the great decrease of German exports of steel and of iron-manganese alloys, the ferro-manganese situation in Germany probably did not become acutely serious for several months after the war started. Substitutes for iron-manganese alloys as re-carburizers of steel have been tried, but according to F. Jovic [53] these proved more costly and yielded such inferior results that their use was abandoned.

The total amount of manganese ore (over 30 per cent. manganese) smelted in Germany during the year 1913 was 700,832 tons [54].

In a paper read before the American Institute of Mining Engineers [55], F. H. Wilcox stated that during the year 1916 piles of slag from old ferro-manganese furnaces in Westphalia, running from 5 to 14 per cent. manganese, were drawn upon, and that U.S. Consul Albert, of Brunswick, Germany, had reported that the village of Adenslidl had been demolished to secure ore running about 22 per cent. manganese. He also remarked that complaints had lately been reported from Dutch sources in regard to the quality of German steel, which was said to be daily proving worse and becoming hard and brittle. The deterioration was attributed to lack of skilled workmen and of manganese.

GREECE.—Important deposits occur on the islands of Milo and Andros, but the quantity of true manganese ore mined is small, the output from these islands and other localities consisting very largely of mangiferous iron-ore. The Kassandra mines in the province of Salonika (until a few years ago included in the Turkish Empire) formerly yielded about 60,000 tons of pyrolusite annually, but no information is available as to their present output. The production of manganese ore in Greece reached a total of nearly 15,000 metric tons in 1902 ; between that year and 1908, the annual output averaged about 7,500 tons. Since then the production has become greatly reduced, sales averaging only about 500 tons per annum for the period 1913-15. It appears,

however, that 1,315 tons of ferro-manganese were produced in 1914, and 1,041 tons in 1915 [56].

ITALY.—Deposits of manganese ore occur in Liguria, Tuscany and elsewhere, but the output is small owing to the high percentage of silica in the ore, as well as to lack of transport facilities. The annual production of that class of ore for the period 1902–11 varied from about 2,000 metric tons up to a maximum of about 5,400 tons (in 1905), the output in the year immediately preceding the war being only 1,649 tons. For 1915, however, the production of manganese ore has been reported at 12,577 metric tons.

There has been a considerably larger production of maniferous iron ore, sometimes exceeding 25,000 tons in a year. In 1911, however, the output of that class of ore fell to 6,482 metric tons, and in 1912 there was no production. Statistics for later years are not available. The mangani-ferous iron ore industry in Italy no doubt suffered owing to her war with Turkey, and may not recover for some time after the European war.

PORTUGAL.—The production of manganese ore in Portugal has never been of considerable importance, and statistics for recent years are not available.

RUSSIA.—The great bulk of the manganese-ore hitherto exported has been obtained from deposits at Tchiatouri (Chiaturi) in the province of Koutais, district of Sharepan, on the southern slope of the central part of the Caucasus mountains. These deposits are said to have been discovered in 1848, but the first shipment of manganese-ore recorded was made in 1879. In the decade 1904–13, the Tchiatouri deposits yielded about 75 per cent. of the total Russian production. The Nikopol district, in the government of Ekaterinoslav, South Russia, where manganese-ore deposits occur in the vicinity of the Dnieper River, about 100 miles from the Gulf of Odessa, has contributed steadily and progressively to the production since 1886, the output for the decade 1904–13 amounting to over 24 per cent. of the total Russian production. Of the Nikopol output, 80 per cent. is delivered to South Russian metallurgical works, the balance of 20 per cent. going normally to Germany [57]. The small remainder



of manganese ore produced in Russia is obtained from deposits in the central part of the Urals (governments of Perm and Orenburg), this output being of only local importance, going to Urals works.

Until the outbreak of the war, Russia had always been the chief producer of manganese ore except for the short period 1908-11, when its output was exceeded by that of India. The war has very seriously affected the Russian industry, practically bringing it to a standstill, exports through the Dardanelles to Great Britain and the United States, as well as into Germany (the largest buyer of Russian ores), having been entirely suspended. The total production of manganese ore in Russia from 1879-1913 amounted to over 12,500,000 long tons. Statistics for recent years are given in the table (p. 6) showing the world's production in long tons. The figures therein show that the highest output attained was reached in 1913, when 1,289,370 long tons were produced, the previous best years having been 1906-7, when the yield averaged just over 1,000,000 tons. In 1914 the production was more nearly normal, amounting to 725,450 long tons, but it has been roughly estimated [58] that the production for 1915 was only 50,000 tons and for 1916 only 150,000 tons.

The development of the industry is hampered by faulty organization, primitive and wasteful methods of mining, and lack of adequate transport facilities, which not only prevents the opening up of new deposits, but involves high railway charges to the ports of shipment. Large schemes are said to have been under consideration for bettering the position of the industry after the war, including improved mechanical equipment for transshipping ore, at Poti and Batoum, and the transformation generally of the latter port.

*Tchiatouri Deposits.*—The ores of the Tchiatouri district are of sedimentary origin, and the deposits are distinctly stratified, the regional rocks being Cretaceous and Tertiary sediments regularly bedded and lying almost horizontally. The total area in which mines occur is said to be about 55 square miles, of which about two-fifths is believed to contain high-grade ore. The average thickness of the mangiferous bed is from 6 to 7 feet, but only about one-half of this is

valuable. Harder [61] estimates that these deposits contain about 110,000,000 metric tons of manganese-ore. H. K. Scott, however, estimates the amount available at about 22,000,000 tons [59]. The ore consists mainly of pyrolusite, but psilomelane and wad also occur. The average percentage of manganese is from 40 to 45, this being raised to about 51 or 52 per cent. by cleaning and sorting. Phosphorus averages about 0.16 per cent., and silica not more than 8 per cent. The ore is softer and more friable than that produced in India, and disintegrates to a serious extent during mining and transportation, this rendering a heavy percentage of the mineral unsuitable for shipment for use in blast furnaces. The ore is hand-sorted at some mines, whilst at others it is screened to get rid of the siliceous gangue and then roughly concentrated on tables or jigs [60]. The ore thus prepared is classified as "very rich," "rich," and "medium," the sorting process yielding about 33 per cent. suitable for shipment. It has to be transported from 1 to 6 kilometres in mine-trucks and 40 kilometres by narrow-gauge railway, and reloaded into broad-gauge wagons for transport to Poti, on the Black Sea (about 90 miles from Tchiatouri), where two-thirds of the ore is shipped, the remainder being exported through Batoum (about 126 miles from the mines). The cost of the ore delivered at Poti, including port charges, is normally 23/8.5, and at Batoum 23/11.5 per ton, including 6/0.5 for actual mining [61].

*Nikopol Deposits.*—These are horizontal beds in Oligocene strata, granite and gneiss occurring at no great depth below. The mangiferous area is estimated at about 8 square miles, the beds averaging from 3 to 5 feet in thickness. The available ore is estimated at about 7,400,000 metric tons, but H. K. Scott and others are of opinion that many times this amount is available. It occurs as nodules of psilomelane and pyrolusite in a bed of sandy clay, and, as exported, averages 46 per cent. of manganese, 12 per cent. of silica, 0.25 per cent. of phosphorus, and 1 per cent. of iron. The better class is said to contain about 57 per cent. of manganese [62].

*The Ural District.*—This has been a steady, although small, producer of manganese ore since 1882. An exceptionally

large yield was obtained in 1912, when the output amounted to 21,487 tons.

Attention has recently been drawn to a new region, the Gaisinsk district, province of Podolia, South-West Russia, 221 miles by rail from Odessa, where there are deposits of pyrolusite apparently of large size and high grade. The Podolia manganese region comprises an area of about 30 square

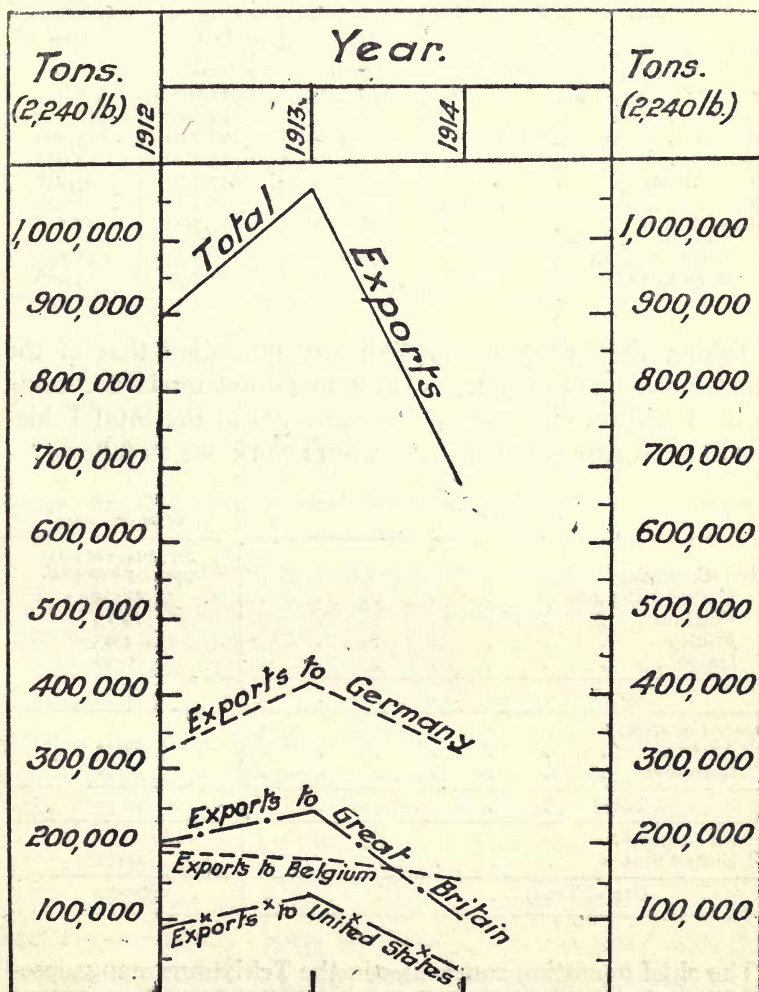


DIAGRAM 5.—EXPORTS OF MANGANESE ORE FROM TCHIATOURI. TOTAL AND TO PRINCIPAL COUNTRIES (1912-1914)



miles, and it is very advantageously situated as regards not only German and Austrian markets, but also exportation of ore from Odessa and Nikolaiev.

*Distribution of Russian (Caucasus) Ores.*—The Tchiatouri ores, constituting about three-fourths of the total Russian production, were distributed during the years 1912–14 as follows [63]. (See Diagram 5, p. 77) :

To	1912.	1913.	1914.
	Tons.	Tons.	Tons.
Germany . . . . .	322,500	412,000	326,403
Austria . . . . .	40,000	25,400	32,435
Belgium . . . . .	193,500	182,500	154,467
France . . . . .	42,200	55,100	23,951
Great Britain . . . . .	202,000	246,500	107,030
Italy . . . . .	—	7,400	—
United States . . . . .	96,300	137,700	34,548
Total Exports . . . . .	896,500	1,066,600	678,834
Unexported . . . . .	17,000	10,000	15,096

Taking the two years immediately preceding that of the commencement of the war, and grouping the countries according to their attitude in 1914, the percentages of the total Tchiatouri actual exports of manganese-ore work out as follows :

To	Years 1912–1913.
<i>Allied Countries :</i>	Percentage of total quantity exported.
United Kingdom . . . . .	22.85
Belgium . . . . .	19.15
France . . . . .	4.95
Italy . . . . .	0.38
Total . . . . .	47.33
<i>Enemy Countries :</i>	
Austria . . . . .	3.33
Germany . . . . .	37.42
Total . . . . .	40.75
<i>Neutral Country :</i>	
United States . . . . .	11.92
Grand Total . . . . .	100.00

The chief operating companies in the Tchiatouri manganese-field before the war are stated [64] to have been the Schalker Gruben und Hütten Verein, of Gelsenkirchen, Germany (which

consumed its own ore); Forward Bros. (English); Panassie (French); and the Industrial and Commercial Company, of Antwerp. The Belgian company has a plant capable of producing 100,000 tons of 53 per cent. to 54 per cent. washed manganese-ore per annum. Numerous other small properties are being worked in crude fashion.

The great increase in German buying of Russian manganese-ore in the year immediately preceding the war and during that part of 1914 when the Russo-German frontier was not yet closed, is perhaps not without special significance.

Recent information from Russia states [65] that while less than 32,758 metric tons of manganese ore were sent away from Tchiatouri in 1915, 255,111 metric tons were despatched from the district in 1916. The Russian works, which formerly obtained their principal supplies from the Nikopol mines, at the rate of about 32,758 metric tons per annum, increased their demands to 196,552 tons in 1916, and, the Nikopol mines being unable to meet this requirement, the bulk of the ore was obtained from Tchiatouri. Of the 255,111 tons despatched from Tchiatouri in 1916, about 49,138 tons were added to the stocks at the port of Poti, where at the end of that year 131,035 metric tons were stored.

The total stock of manganese ore in the Caucasus at the end of 1916 was about 917,246 metric tons, as against 1,716,000 tons in hand at the end of 1914 [66].

SPAIN.—The deposits of manganese ore chiefly worked hitherto are situated in the province of Huelva, the mineral being a carbonate. About the beginning of 1915 [67] a manganese field was opened in Sevilla and another in Ciudad Real, and shortly afterwards new workings were opened in Huelva (where the known deposits had to a large extent become exhausted), Gerona and Oviedo. In Sevilla the manganese beds lie along the Silurian slates, and in Ciudad Real are the bases of little Tertiary hills interbedded with the Miocene limestone. A few years ago, new deposits were discovered in the province of Teruel, where the ore is a silicate containing 33 per cent. of manganese and from 30 to 37 per

cent. of silica. This has been exported to Belgium and Luxembourg, and smelted with aluminous iron ores. Spanish manganese-ore is commonly sold on the basis of its percentage of manganese dioxide.

The annual output of manganese ore exceeded 100,000 tons during the years 1897-1900, but the production has since been irregular and decreasing. In 1907, exports made a notable recovery, amounting to 68,000 metric tons; but the period 1909-11 was the worst on record, production averaging only about 7,300 tons a year.

Subsequent production and shipments have been as follows [68]:

Year.						Output.	Exports.
						Metric tons.	Metric tons.
1912	.	.	.	.	.	19,936	29,764
1913	.	.	.	.	.	21,594	27,793
1914	.	.	.	.	.	<sup>1</sup>	8,965
1915	.	.	.	.	.	14,328	9,136
1916	.	.	.	.	.	14,178 <sup>2</sup>	6,815
1917	.	.	.	.	.	57,474 <sup>2</sup>	<sup>1</sup>

<sup>1</sup> Statistics not available.

<sup>2</sup> Official.

There is normally a large export of mangiferous iron ores, but the production in 1917 amounted to only 50 tons.

SWEDEN.—The chief producing districts are Udenäs (Bölet), West Gothland, Wermland, and Jönköpings. Three types of manganese ores occur: (1) pyrolusite with manganite, (2) hausmannite with braunite, and (3) carbonate and silicate of manganese accompanying iron ores. The annual output, which is comparatively small, is given in the table showing the world's production. The difficulty attending the lack of manganese in Sweden since the outbreak of the war appears to have been to some extent overcome by the use of ferro-silico manganese. Ferro-manganese is also produced in Sweden in the electric furnace, but it is not suitable for all purposes, on account of the comparatively high silicon content [69].



The production of ferro-alloys in the electric furnace in Sweden for recent years has been as follows <sup>1</sup>:

(Metric Tons)

—	1913.	1914.	1915.
Ferro-silicon . . . .	9,863	8,732	11,819
Silico-manganese iron . . .	1,375	1,304	2,328
Ferro-manganese . . . .	—	293	947

In addition there was a small production of ferro-chrome (averaging about 770 metric tons per annum for the three years). The combined production of ferro-silicon and silico-manganese iron in 1917 was 18,000 tons, and in 1918, 11,600 tons.

TURKEY.—The output of manganese-ore in European Turkey has been principally obtained from the Kassandra mines in the province of Salonika (now included in the Kingdom of Greece), which formerly yielded about 60,000 tons of pyrolusite annually. A similar amount is said to have been obtained from deposits in the Phlinika district, Asia Minor, which yielded ore containing 52 per cent. of manganese. Small quantities of ore are also obtained from the vilayets of Trebizonde and Aidin.

According to E. Halse [70], important deposits of manganese ore in serpentine were opened up, not long before the war, in the vilayet of Aidin; and he has personally examined deposits of that ore at Pirga, in the vilayet of Trebizonde. These latter occur, about 500 feet above sea-level, a few miles from Surmeneh on the Black Sea. The ore, chiefly psilomelane and manganite, fills irregular pockets, pipe-like openings and fissures in limestone, and occurs in lumps mixed with red and yellow clay, fragments of limestone, etc. A few of the deposits at Pirga had been worked on a small scale about 23 years before, but nothing was seen in any way comparable with the Caucasian (Tchiatouri) deposits. Many stringers of manganese ore occur also in the altered porphyry, but these are unworkable.

<sup>1</sup> Quoted from *Statistical Report*, 1916—Iron, Steel and Allied Trades Federation.

Statistics of production for recent years are not available. The official report of the Department of Mines and Forests of Turkey, for the fiscal year ending March, 1909, gave the production of manganese-ore in 1908 as 14,349 metric tons, value £19,617; and in 1909 as 7,578 metric tons, value £10,000.

It is stated that shipments of ore containing 85 per cent. of manganese dioxide and less than 1 per cent. of iron have been made from Turkey to the United States. This was probably used in the manufacture of dry electric batteries.

A selling basis of 45 per cent. of manganese is common in the case of Turkish ores, which are somewhat more variable than the high-grade ores of Russia, India and Brazil.

## ASIA

JAPAN.—There are numerous occurrences of manganese-ore in Japan, and the country has been a steady producer for many years, the output for 1896 amounting to 17,967 metric tons, the highest production recorded being 54,339 tons in 1906. The production in later years is stated in the table showing the world's production.

Manganese-ore is widely distributed in Japan, occurring in most of the provinces, but the deposits do not appear to be extensive. Among the well-known mines are the Mirika, in Hokkaido, the Takasaki in Aomori prefecture, and the Kitayama in Kyoto. The manganese-ore of economic importance is most probably a mixture of oxides (psilomelane, pyrolusite, etc.). The ore occurs mostly in rocks of the Palæozoic age, but also, less widely distributed, in the Tertiary and still later formations. In the older rocks it is found, as a rule, exclusively in the zone of oxidation, and is easily mined by open cuts or shallow pits. In the majority of cases, the deposits are lenticular or irregular in form, varying in size from a small lump up to a mass weighing a hundred or more tons. The most widely distributed and economically important ore is for the greater part found in quartzite, hornstone, radiolarian slate, or schalstein [71]. Alabandite (MnS) associated with rhodochrosite occurs in large quantities in the silver veins at Innai, in the province of Akita [72]. The ores exported

are fairly high grade, and average about 52 per cent. of manganese and from 0.16 to 0.8 per cent. of phosphorus. The selling basis for Japanese manganese-ores, which are rather more variable than those exported from Russia, India and Brazil, is commonly 45 per cent. of manganese. At Hamburg they have realized prices ranging from £2 10s. to £5 15s. per ton according to quality.

According to G. T. Holloway [73], the Japanese "brown-stone" ore (pyrolusite) is specially suited for chemical purposes, and fetches a higher price than others per unit of manganese. It varies in composition from about 43 to 56 per cent. of manganese, 7 to 10 per cent. of silica, and carries about 0.5 per cent. of phosphorus. It is commonly sold for its value in available peroxide, the schedule being agreed at so much per ton if from 85 to 90 per cent. manganese dioxide, or so much if from 75 to 85 per cent., 70 to 75 per cent., or 65 to 70 per cent. Japanese brown-stone containing 87 per cent. of manganese dioxide (about the best obtainable) fetches about twice as much as 70 per cent. ore; while certain Continental pyrolusites, containing about 50 per cent. of available manganese dioxide, and stated to be marketable in the United States, fetch only about one-fifth as much as the 87 per cent. Japanese ore. In 1917, the United States imported 2,745 tons from Japan.

JAVA.—Deposits of manganese ore have been worked in the Regencies of Pengasih and Nanggolau, but the production is of unimportant size. Occasional shipments have been made to the Mount Morgan gold mine, Queensland.

DUTCH-BORNEO.—Manganese ore is known to occur at Gunong Bessi (= iron hill) in South Borneo. About  $1\frac{1}{2}$  miles north-west of Pengaron, there is an isolated hill, about 150 feet in height and 2,500 feet in circumference, described by Posewitz [15] as lying near a dyke of augite-andesite, cutting late Tertiary sandstone strata. The hill is covered with a thick layer of earth and numerous boulders, many of which measure from 1,500 to 2,000 cubic feet. These boulders consist of a very hard steel-grey manganese dioxide, usually with a blackish deposit of wad on the surface. The occurrence was confirmed as early as 1858. A detailed investigation carried out in



1883 showed that these boulders were derived from a vein about 30 feet in thickness, traversing a grey andesitic tuff, and having the same strike and dip as the coal-seams of Pengaron. According to Hooze, it is a case of lateral secretion. The amount of manganese peroxide in the ore is very variable, samples taken by Hooze assaying up to 78·7 per cent. An analysis made at Freiberg, in Saxony, gave 97·27 per cent. of manganese dioxide.

C. M. Schwaner found small quantities of psilomelane in different localities of the former kingdom of Bandjermassin, in South-East Borneo [15].

PHILIPPINES.—The most important and best-known deposit of manganese-ore in these islands occurs in the eruptive conglomerate region of Nagpartion, in the province of Ilocos Norte. The occurrence is described [74] as a system of veinlets of pyrolusite between boulders of eruptive material. The matrix is a soft and yielding tuff. This material has been decomposed, resulting in a concentration of nodules of pyrolusite in the depression between the adjacent hills of tuff. The original veinlets are only from 5 to 50 mm. in width. Developments between Punta Negra and Punta Blanca have indicated that, although the lateral extent of the nodule concentration is considerable, the thickness of the deposit is small. The nodules are of very good quality, containing 77·5 per cent. of manganese dioxide, only 0·02 per cent. of phosphoric anhydride, and 1·1 per cent. of silica. Two other deposits are known, one in the island of Masbate, which is said to be of promising appearance.

Up to the end of 1915 [75] the only production of manganese ore in the Philippine Islands that had been recorded was in the year 1909, when ore to the value of £1,300 was mined. In 1917, from 2,000 to 3,000 tons of ore were shipped from deposits in Ilocos Norte. Japan has been mentioned as a possible buyer of such ore from the Philippines. Lack of shipping facilities is a great difficulty.

PORTUGUESE INDIA.—Deposits of manganese ore, usually psilomelane or pyrolusite, separate or associated, are widely distributed in Goa; but they occur so irregularly, and are so variable in composition, that they are of comparatively

little importance. In all cases they are overlaid by a thick bed of true laterite, which enhances the cost of quarrying to such an extent as to render the operation barely profitable. The ore hitherto produced has not been of high grade. Exports for 1907 amounted to about 12,580 tons, but the fall in the market-price of manganese-ore in 1908 resulted in a general suspension of work. During the period 1909-13, an average of 3,250 tons of ore won in Goa was annually exported from Mormugao, the quantity for 1913, however, being only 1,556 tons [76].

### AFRICA

*Belgian Congo.*—Manganese ores have been found in the Katanga, where they are frequently associated with the iron deposits, but their economic value has not yet been proved. A rather large deposit in the valley of the Fungwe River consists of lenses of high-grade manganese-ore and quartz at the contact of biotite granite and norite with an older muscovite granite. This deposit has been variously described as a contact deposit, or perhaps a magmatic segregation, or a vein [77].

*"German" East Africa.*—Manganese ore occurs in the Unata district, some 25 kilometres west-north-west of Ikoma; and psilomelane has been found in the Kipengele Hills, in the Livingstone Mountains.

### AMERICA

*UNITED STATES.*—The proportion of manganese ore properly mined in the United States before the war was a quite negligible quantity, being only about the same as that of the United Kingdom. E. C. Harder [78] explains the fact of the manganese mining industry in the United States never having attained importance as being due to the small extent and the discontinuous and scattered nature of most of the deposits. Nearly all the ore mined must be either washed or sorted, or both. The small extent of the pockets of ore does not encourage companies to erect expensive concentrating plants. In general, the ore is low in manganese and high in silica.

The following table, compiled from various official sources, shows the insignificance of the manganese ore output of the United States in recent years :

(Long Tons)

State.	1912.	1913.	1914.	1915.	1916.
California . . . .	—	—	501	2,563	13,404 <sup>2</sup>
South Carolina . . . .	—	—	410	—	—
Georgia . . . . .	—	—	—	3,168	—
Virginia . . . . .	1,664 <sup>1</sup>	4,048 <sup>1</sup>	1,724	1,620	—
Other States . . . .	—	—	—	2,358	—
Total . . . . .	1,664	4,048	2,635	9,709	26,966

<sup>1</sup> Includes Tennessee and California. (1913 figures include small productions in 1911-12.) In 1917, California produced 15,515 tons, the estimate for 1918 being 25,000 tons.

<sup>2</sup> *Calif. State Mining Bureau, Press Bull.* 43, Dec. 3rd, 1917.

It will be seen that the marketed domestic production of manganese ore increased, owing to the cutting-off of supplies from Russia and short shipments from India, from an average of only about 2,800 tons a year for the three years 1912-14 to about 27,000 tons (the actual weight was probably about 33,000 tons) for 1916, the production for that year being the highest till then reached since 1888. The estimate, of course, does not include the mangiferous iron ores containing less than 40 per cent. of manganese. The domestic production of manganese-ore marketed in 1917 is estimated at 122,275 tons [79].

According to *The Mineral Industry* [80], the 1916 output came largely from seven States, the order in production being probably California, Arkansas, Arizona, Georgia, Virginia, Utah, Colorado. It is remarked that the year in question was the first in which a Western State remote from the steel-producing centres has contributed the largest amount of manganese-ore. The activity among manganese mines in California is stated to be due largely to the market for ores provided by the Noble Electric Steel Co. at Heroult, Shasta County, California.

*California.*—The characteristic occurrence of manganese ore in California, as described by E. C. Harder [81], is in the



form of porous black oxide, associated as layers and pockets with the jasper lenses of the Franciscan formation of the Coast Ranges. Smaller deposits are found in the Sierra Nevadas, in veins in the Calaveras formation, as fragments disseminated in auriferous gravels, or in deposits associated with igneous rocks. Recent investigations by the California State Mining Bureau have proved the occurrence of important deposits of manganese ore, in Inyo and San Bernadino counties, as replacements in limestone or along contacts between limestone and granite. The deeper workings of the Ladd and Merchant Mines in San Joaquin and Alameda counties are yielding the grey carbonate of manganese, rhodochrosite, as a commercial ore [82]. Siliceous manganese ores are very common in California.

*Virginia.*—The largest deposit of high-grade manganese ore hitherto discovered in the United States appears to be that at Crimora, Augusta county, Virginia, from which some 350,000 tons of ore have been produced during the past thirty-five years. The deposit is described by E. C. Harder [83] as consisting of manganese ore masses of various sizes scattered through variegated clays in a canoe-shaped syncline of the Cambrian quartzite. The basin has a general north-south trend, and is about half a mile in length, several hundred yards in width, and 200 feet in depth. It occupies a flat area bounded on the east and north by spurs of the Blue Ridge. The clays are for the most part residual from the upper Cambrian shale, and are white, yellow, orange, brown and black in colour. In general they are stiff, but here and there are masses of yellow sandy clay, or white sand, or fragments of undecomposed sandstone. The black manganiferous clay generally occurs in separate beds, lenses, or irregular pockets, or interlaminated with the other clays, while the light-coloured clays as a rule are intimately intermixed. Stiff orange and yellow clays are the most abundant, and contain most of the ore. The residual clays are covered by a layer of drift averaging about 15 feet in thickness.

The ore is hard and of three varieties: (1) kidney ore of bluish-black psilomelane in stiff orange and yellow clay; (2) irregular pockets of pyrolusite and psilomelane in man-

ganiferous clay; and (3) replacements and cavity fillings of psilomelane and pyrolusite in sandy clay.

The kidney ore is the most abundant and occurs in lumps of rounded, irregular shapes, a few inches in diameter.

An analysis of the best quality of ore from the Crimora mine shows 57.291 per cent. of manganese; 0.373 per cent. of iron; 2.132 per cent. of silica; 0.075 per cent. of phosphorus. Average analyses of actual shipments during 1887 and 1888 indicate that the average percentage of manganese is slightly under 50, the percentage of silica being rather high and at times excessive, that of phosphorus satisfactorily low, iron varying from 2 up to as much as, exceptionally, 4.5 per cent.

Virginia appears to possess a larger number of deposits of manganese ore than adjacent States, and, owing to this fact and to the proximity of markets, it has supplied a large part of the domestic production. For the period 1880-1914 the average proportion was 61 per cent., and of this ore nearly two-thirds is said to come from the Crimora mine [84]. No other deposit in this region, from Maryland to Alabama, has yielded more than 50,000 tons of manganese ore. The majority of those that are known have been, or are being, worked, and D. F. Hewett [85] is of the opinion that they are unlikely to average more than 10,000 or 15,000 tons each in total production.

*Georgia.*—This was formerly (from 1866) one of the principal producing States, her strongest competitors being Virginia and Arkansas; but there had been no important production in that State since 1902 until the year 1915. The commercially valuable deposits of Georgia are entirely limited to the northern part of the State, and to certain areas in the Palæozoic group [86].

*Arkansas.*—Some attention is now being given to certain deposits of manganese-ore, hitherto unexploited, in the Ouachita Mountains, west-central Arkansas. According to H. D. Miser [87] the ores occur as nodules, pockets and short irregular veins varying in width from less than an inch to, rarely, 4 feet. The ore bodies are described as being scattered through hard novaculite, the ore being generally con-

fined to two stratigraphic horizons in it, occupying bedding planes or joint cracks, or forming a cement in a novaculite breccia. Most of the ores contain too much phosphorus for use in the manufacture of ferro-manganese, and too much iron for use in the chemical and dry battery industries. It is stated in *The Mineral Industry* [88] that several prospects now show a width of 3 feet and over of solid psilomelane, the ore giving returns of 50 to 60 per cent. of manganese, up to 8 per cent. of silica, and about 0.2 per cent. of phosphorus. The deposits have hitherto been worked only in a small way, and only a few hundred tons of ore therefrom have been marketed.

The Batesville field, in Independence and Izard counties, Arkansas, the output from which was negligible before the war, is now producing about 2,000 tons a month of hand-cobbed and fine-washed manganese-ore [89]. The ores, which comprise various oxides, occur in a residual clay derived from the decay of a bed of overlying limestone, the distribution of the ore in the clay being irregular. The pockets are sometimes comparatively solid bodies separated only by thin seams of clay, containing from 50 to 500 tons of ore; or they may consist of large and small masses of ore imbedded in greater or lesser quantities in certain places in the clay; whilst the ore has been found also in the form of small nodules or grains, disseminated throughout the clay. Most of these pockets of "wash dirt" contain from 5 to 25 per cent. of manganese ore. Some ore has also been found in its original form in broken limestone boulders that have not yet disintegrated. The ore classed as "high grade" runs from 40 to 58 per cent. of manganese, the "low grade" from 40 to 17 per cent.

*Montana.*—It was reported in 1917 that large deposits of manganiferous iron ore, averaging from 30 to 40 per cent. of manganese, had been discovered in Western Butte, Montana [90]. The desirability of exploiting all the available sources of manganese in the United States during the war has resulted in the manganiferous gangue of the silver-zinc lodes of these Montana ores, formerly regarded as waste, being worked as a source of manganese. With prices for



manganese oxides in the United States as at present, this is economically practicable.

The mangiferous mineral in the outcrops and upper portions of the lodes is low in manganese and very high in silica, reserves of such material assaying as follows [91]:

Tons.	Mn per cent.	SiO <sub>2</sub> per cent.
26,000 . . . . .	40.0	10
132,000 . . . . .	24.0	50
270,000 . . . . .	11.5	73

It is regarded as possible that the second-class might be concentrated. The greater part of the mangiferous material, however, lies below the oxidized zone, and consists of the carbonate of manganese (rhodochrosite) and the silicate (rhodonite).

In the Emma mine, the carbonate ore carries from 34 to 41 per cent. of manganese and only 1 per cent. of silica, and the manganese content is increased by a light roasting, which drives off carbon dioxide. Several thousand tons of this ore are said to be available, and large additional quantities are likely to be developed. The amount of lower-grade material, averaging 15 per cent. of manganese, is estimated at several million tons. The manganese ore output of the Emma mine was recently stated to be about 300 tons a day [92], but the average analysis is not available. Most of the mangiferous lodes at Butte carry less than 40 per cent. of manganese; they are high in silica, and contain from 3 to 4 per cent. of iron.

A plant for the mechanical concentration of manganese-ore has been in continuous operation by the Philipsburg Mining Company, at Philipsburg, Montana, since January 1918 [93]. The manganese mineral occurs in a limestone formation and consists chiefly of a nodular variety of pyrolusite and psilomelane. A fair average of the assays is said to be as follows:

	Manganese per cent.	Silica per cent.
Heads . . . . .	32	35
Washed ore (coarse) . . . . .	41	18
Concentrate . . . . .	49	9

The plant is described in the article from which these figures are quoted.

*Colorado.*—Two great lenses of manganiferous iron ore, estimated to contain more than three-quarters of a million tons of ore averaging from 12 to 15 per cent. of manganese, 38 per cent. of iron, 1 to 2 per cent. of silica, and low in phosphorus, are reported [94] to have been recently found in the Red Cliff or Battle Mountain mining district, 20 miles north-north-west of Leadville, Colorado.

The principal ore bodies occur as lenses parallel with the bedding of the enclosing Carboniferous limestone, which dips 15° to the north-east, and it is considered probable that other ore bodies will be found. In San Miguel county, Colorado, a high-grade manganese-ore deposit is being developed, from which it is claimed that large shipments can be made of ore with 85 per cent. of manganese dioxide and less than 1 per cent. of iron, such as had been imported from Turkey [95]. This is close to the British specification for manganese-ore for dry batteries.

*Nevada.*—Deposits of manganese ore in the Ely and Siegel districts, White Pine County, Nevada, have recently been examined by the United States Geological Survey [96]. The ore extends from the surface to a depth of 50 feet or more. Practically all the deposits occur in limestone and are associated with bodies of jaspery quartz. The ore bodies are irregular pipes, pockets and lenses ranging from a few feet to 70 feet or more in length, and from a few inches to 10 or 20 feet in width. Several of the larger bodies contain from 500 to 1,000 tons or more. The bulk of the ore is composed of the softer manganese oxides, pyrolusite being predominant in some mines and wad in others. The ore mined contains from 36 to 45 per cent. of manganese, 3 to 5 per cent. of iron, 3 to 16 per cent. of silica, a moderate amount of lime, and a little phosphorus. Most of the ores contain more or less silver. Small shipments of ore have been made, and it is estimated that about 25,000 tons are now in sight, of which, however, only one-fifth is high-grade manganese-ore, the remainder containing a high percentage of silica, and a considerable amount of iron.

*Utah.*—Several deposits of manganese ore occurring in southern Utah, near Monroe, Sevier county, and near Marysvale, Piute county, have recently been examined by the U.S. Geological Survey [97]. These deposits lie along the eastern boundary of Sevier Valley, at the base of Sevier Plateau, which is underlain by igneous rocks, chiefly Tertiary tuffs and lavas. The Loring deposit lies 6 miles south of Monroe, near the base of Monroe Peak. Assays of small shipments made in 1916 showed the ore to contain 35 per cent. of manganese, 6.6 per cent. of silica, and 8.57 per cent. of iron. The ore occurs in cracks and crevices of weathered igneous rock, under an overburden having a maximum depth of 16 feet. Small lenticular masses of manganese and iron oxides in tufa have been found a short distance east of Monroe. Near the mouth of Manning Canyon, 10 miles south-east of Marysvale, a deposit of manganese-ore has been exposed in several open cuts, its outcrop being traceable for 400 feet. The enclosing rocks are lavas of several varieties, but most of the ore is disseminated through a flow of rhyolite which ranges in thickness from 8 to 30 feet. Small shipments of manganese-ore have been made from a deposit near Junction, Piute County, and from a deposit near Pahreah, Kane County, Utah.

Manganese-ore occurs also in other States, notably *Arizona* and *Tennessee*, where production is increasing.

The activity in manganese ore mining in the Western States is attributed partly to the operation of electric reduction plants in California and Washington, but more largely to the low percentage of iron in some of the Western ores [98]. Few Eastern American mines that operate residual products can produce at a profit in large quantities ore that contains less than 1 per cent. of iron, and therefore most of the Eastern mines ship their product to Eastern furnaces to be reduced to ferro-manganese. The inaccessibility of most Western deposits makes it unprofitable to ship ore to Eastern makers of ferro-manganese, even at the high prices they are now offering for manganese ore. At prevailing prices for the high-grade ores, these may be profitably shipped as far east as New York.



It has yet to be proved that the United States deposits of high-grade manganese ore are sufficiently extensive and occur under such conditions as to allow of increasing and profitable exploitation after the war, when the Indian and Russian ores are again freely available.

In order to supply the enormous deficiency between the domestic output and the requirements of high-grade manganese-ore, foreign supplies have had to be depended upon, the principal contributors to American imports being, in order of importance prior to the war, British India, Russia and Brazil.

*Imports of Manganese Ore into the United States (1912-16)*<sup>1</sup>  
(Long Tons)

From	1912.	1913.	1914.	1915.	1916.	1917. <sup>2</sup>
British India .	128,645	141,587	103,583	36,450	51,960	48,975
Russia .	83,334	124,337	52,681	nil	nil	nil
Brazil .	81,580	70,200	113,924	262,584	495,179	512,517
Other Countries	7,102	8,966	13,106	21,748	29,182	68,480
Total .	300,661	345,090	283,294	320,782	576,321	629,972

The percentages of imports of the mineral into the United States from the three principal sources of supply during the same years were as follows :

From	1912.	1913.	1914.	1915.	1916.	1917.
	%	%	%	%	%	%
British India .	42.8	41.0	36.6	12.5	9.0	7.8
Russia .	27.7	36.0	18.6	0.0	0.0	0.0
Brazil .	27.1	20.3	40.2	81.8	85.9	81.4

From these two tables and Diagram 6 (p. 94) it will be seen that, in the pre-war years 1912-13, the imports of manganese ore from India were larger than those from any other country, while in 1912 imports from Russia and Brazil were practically

<sup>1</sup> *Min. Resources of the United States, U.S. Geol. Survey.* The figures for Brazilian exports to the U.S. in 1915 and 1916 are as quoted from *Report of the Brazilian Ministry of Finance in the Bulletin of the Pan-American Union*, after conversion from metric tons, <sup>2</sup> *The Mineral Industry, 1917.*

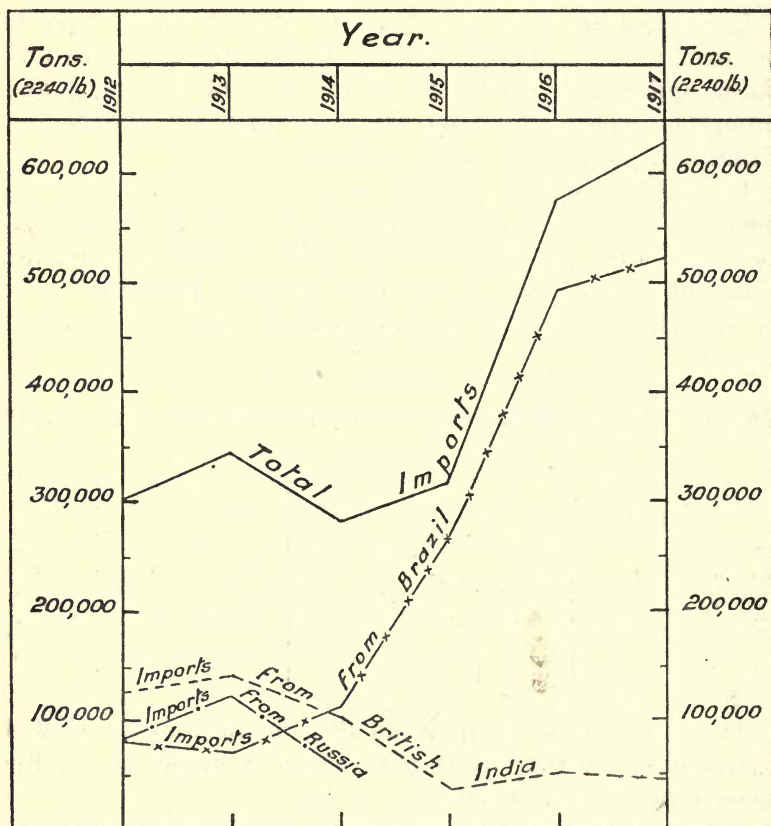


DIAGRAM 6.—IMPORTS OF MANGANESE ORE INTO THE UNITED STATES, TOTAL AND FROM CHIEF PRODUCING COUNTRIES (1912-1917).

of equal amount. In 1913, the imports of manganese ore from Russia had increased by more than 8 per cent. of the total imports, while those from Brazil had decreased by nearly 7 per cent. After the outbreak of war the situation was completely changed, Russian exports ceasing with the closing of the Dardanelles, while supplies from India were greatly curtailed. In these circumstances the imports from Brazil were very largely increased, exceeding in 1916 the total imports of manganese ore into the United States in the previous record year, 1913. In 1916, there was, also, an appreciable increase in the imports from India, as compared with 1915, while the imports from the minor sources (chiefly Japan, Cuba and Panama) were more than

three times as great as in 1915 [98]. (See JAPAN, and CUBA.)

Under war conditions Brazil is able to supply the United States with most of the manganese ore required, but it is a matter for conjecture whether she can retain her present position as chief supplier of American requirements when India and Russia are again in competition under more normal conditions, and the price of delivery becomes once more a deciding factor. At present American producers of ferro-manganese are almost entirely dependent on ores from Brazil, with the result that price has become a secondary consideration.

Sales of Brazilian ore were made in 1915 at as high as 44 cents per unit at Rio de Janeiro, equal to about 56 cents at United States Atlantic ports [99]. A year before, it was sold at 18 cents at Philadelphia. A contract for the delivery of 200,000 tons of Brazilian ore during 1917 is said to have been placed at \$23 per ton f.o.b. Brazilian port, from which the freight rate to Baltimore is \$12 per ton, making a total of \$35 per ton [98].

The War Industries Board of the United States have fixed a price schedule for manganese ore, excluding chemical ores required for dry batteries, etc. For ore containing from 39 to 39.39 per cent. of manganese, the price is \$1 per unit, with an addition or deduction of 2 cents for every per cent. over or under that proportion between 35 and 54 per cent.

While the production of manganese ore proper in the United States has until quite lately been so insignificant, there is a great output of manganiferous iron-ores, large deposits of which occur in the New England, Appalachian, and Lake Superior regions. Of these, the Lake Superior Iron District has been the chief producer of such ores, having hitherto furnished at least 90 per cent. Deposits of minor importance are found in the southern Mississippi Valley, and in the Rocky Mountain region, there being a quite useful production in Colorado. The production of manganiferous iron-ores exceeded 1,000,000 tons in 1906, and has averaged more than half-a-million tons over a long series of years. The output for 1914 fell to 445,827 tons (having been over



672,000 tons in 1913 and 868,500 in 1912), but recovered to 801,290 tons in 1915. (For later figures, see Footnote, p. 5.)

The manganiferous iron ore output of the Lake Superior district contains from 12 to 25 per cent. of manganese, and is used, principally, either for making spiegeleisen, or for mixing with high-grade imported ore in the making of ferro-manganese. Some of the manganiferous iron ores of this and the Appalachian region are so low in manganese that they are classed as iron-ores, and are used in the blast-furnace for the production of "high-manganese" pig iron.

E. C. Harder [100] reckons among the most important deposits of manganiferous iron-ore in the United States those of the Cuyuna iron-ore district of Minnesota, from which the first shipment of manganiferous iron ore was made so recently as 1913. There appear to be a number of separate deposits in the Cuyuna Range, possibly fifteen, of ore ranging from 1 to 35 per cent. manganese, 20 to 50 per cent. iron, and 8 to 16 per cent. silica. The largest deposit known in the district is estimated to contain about 3,000,000 tons, but the deposits of ore with more than 15 per cent. manganese appear to be smaller and to range from 100,000 to 500,000 tons. The reserves of ore with more than 10 per cent. of manganese are estimated to exceed 4,000,000 tons, and it is believed that further exploration by drilling will reveal other deposits of similar material. Those already known in the district are regarded as constituting the greatest localized source of manganiferous iron-ore in the United States.

In addition, the manganiferous zinc ores of New Jersey, already referred to, have been extensively mined, the annual production for several years past having exceeded 100,000 tons, and reaching the exceptionally high total of 159,318 tons in 1915.

It has nevertheless been necessary to import not only very large quantities of foreign manganese ores, but also a great amount of iron-manganese alloys, more particularly ferro-manganese, such imports amounting normally to something like one-half of the domestic production of such alloys, as will be seen from the following table based on official figures:

Year.	1913.	1914.	1915.	1916.	1917.
	Tons.	Tons.	Tons.	Tons.	Tons.
<i>Production:</i>					
Ferro-manganese .	119,496	106,083	146,542 <sup>1</sup>	221,532	257,842
Spiegeleisen .	110,338	79,935	93,282	194,002	188,852
Total Production .	229,834	186,018	239,824	415,534	446,694
<i>Imports:</i>					
Ferro-manganese .	128,070	82,997	55,263	90,928	45,381
Spiegeleisen .	77	2,870	200	nil	nil
Total Imports .	128,147	85,867	55,463	90,928	45,381
Total of Production and Imports . . .	357,981	271,885	295,287	506,462	492,075

<sup>1</sup> *Metal Statistics*, New York, 1918, gives 149,521 tons.

It will be seen that, whereas the domestic production of iron-manganese alloys (ferro-manganese plus spiegeleisen) in 1917 was nearly twice that for 1913, the imports of such alloys amounted roughly to only one-third of the total for that year. The rapidity of the increase in the consumption of ferro-manganese in the United States in recent years will be seen when it is mentioned that the imports of that alloy into the country averaged only 66,642 tons per annum for the 10 years 1902-11, while the domestic production for the same period averaged only 57,990 tons. The figures for 1912 were 99,137 tons and 125,378 tons respectively.

The average value per ton of the imported ferro-manganese was \$44.37 in 1913, \$41.33 in 1914, \$60.31 in 1915, \$101.62 in 1916, and \$134.58 in 1917, the figures representing value at foreign port, without freight or duty. The average monthly price of the alloy at eastern seaboard, based on actual sales, was \$58.04 in 1913 and \$161.37 in 1916. In 1917, British ferro-manganese was sold at from \$325 to \$375 per ton at eastern seaboard.

The price of spiegeleisen carrying 20 per cent. of manganese ranged during the year 1916 from \$52 per ton (in July) to \$40 (in December) [101]. In 1917, it was sold at about \$65 per ton. The price in 1914 was about \$25.

During 1916 approximately 43,800,000 tons of steel of all grades were produced in the United States. Making the

reasonable assumption that stocks at the beginning and at the end of the year were approximately the same, D. F. Hewett [102] suggests that 312,000 tons of ferro-manganese and 194,000 tons of spiegeleisen (that is to say, the total amounts of the two alloys imported into and produced in the country) were consumed to make 43,800,000 tons of steel. The Sub-Committee on Ferro-Alloys of the Advisory Commission of the United States Council of National Defence estimated that for the year 1917 more than 45,000,000 tons of steel would be produced, and the Sub-Committee wished to count on 400,000 tons of ferro-manganese and approximately 200,000 tons of spiegeleisen. In order to make that quantity of ferro-manganese, nearly 850,000 tons of high-grade manganese-ore, with more than 45 per cent. manganese, and 500,000 tons of manganiferous iron-ore and manganiferous zinc residuum would be needed. It was expected that the imports of ferro-manganese in 1917 would be lower than in 1916, and that, in order to obtain the 400,000 tons of ferro-manganese, 700,000 tons of ore would have to be produced or imported. Actually, 629,972 tons of ore were imported into the United States in 1917, the remainder of the ore consumed being supplied from United States mines, working at full capacity [103]. (The Brazilian Ministry of Finance, Office of Commercial Statistics, has published figures showing that 524,434 long tons of manganese ore were exported to the United States in 1917. This represents 83½ per cent. of the total imports of manganese ore into the United States during that year. According to *The Mineral Industry*, 1917, however, only 512,517 tons of Brazilian ore were actually received in that year.)

With open-hearth furnaces working to the limit of their capacity, the shortage of foreign ferro-manganese supplies has had a serious effect upon the American steel industry, and spiegeleisen has of necessity been extensively employed as a substitute for the higher alloy. Normally, in American practice, the open-hearth process uses ferro-manganese of 80 per cent. Mn, while the Bessemer process uses spiegeleisen with 20 to 30 per cent. Mn. The prevailing high prices of manganese alloys have caused attempts to be made to use an alloy of iron, carbon



and silicon to replace part of the ferro-manganese commonly added, and it has been claimed that experiments have proved satisfactory.

The rôle of manganese is largely as a deoxidizer, and J. E. Johnson [104] has stated that experiments in the use of ferro-silicon as a substitute have not been very successful, at any rate to a greater extent than as a substitute for about 25 per cent. of the ferro-manganese. The silicon appears to be less efficient as a deoxidizer, and it has been his experience that oxygen remains in metal when 2 or 3 per cent. of silicon is present, whereas it would immediately vanish in the presence of 1 per cent. of manganese. Aluminium as a deoxidizer could not be used in large quantities. Another important consideration is the fact that manganese seems to affect the rolling properties of the steel. Johnson does not believe that any adequate substitute is possible.

Describing his preliminary studies on the concentration of manganese ores, E. A. Hersam, Professor of Metallurgy at the University of California, has made the following observations [105]: Californian ores are usually low in manganese, high in silica, and laden with gangue minerals; phosphorus is below 0.2 per cent. (the penalty limit). Steel makers demand a 48 per cent. ore, for which \$50 per ton was paid (January, 1918), but the sorting of ores to this percentage is wasteful. Standard concentration by jigs, classifiers, shaking tables and vanners is commercially questionable. Judging by tests that have been made in the University of California laboratory, with a Wetherill machine, magnetic concentration is practicable; drying or calcining of the ore may be desirable. A recovery of 80 per cent. of the manganese in a marketable product may be expected. Flotation tests have not been favourable, the tailing frequently containing more manganese than the original ore. Electrostatic separation is incomplete and not likely to be important. The chemical extraction of the raw or roasted ore by sulphuric acid seems feasible; recovery of the manganese by electrolysis contains many elements of success. He believes that the essentials of manganese ore-dressing are careful crushing and dry magnetic concentration; where the ore bodies are of sufficient magnitude,

chemical extraction may, in certain instances, be found profitable.

COLOMBIA AND PANAMA.—Deposits of manganese ore occur in a region situated on the Caribbean coast extending from Puerto-Bello in an easterly direction for 35 miles towards Point San Blas. The Soledad mine, situated 35 miles south-east of Nombre de Dios, has furnished most of the ore hitherto exported from this region. The ore consists chiefly of psilomelane, with some braunite and pyrolusite, and occurs in irregular lenticular masses, varying in size from a few inches up to 50 feet, in a decomposed shale. After hand-picking, washing and screening, the ore exported generally contains 57·8 per cent. of manganese, 4·18 of silica, 2·73 of water, and 0·06 of phosphorus.

The principal exports have always been made from Panama. No statistics of production are available.

In 1916 it was reported [106] that an American syndicate had recently opened a manganese mine at Madinga, on the Gulf of San Blas, in the Province of Colon, Colombia, about 70 miles east of the city of Colon, and that a trial shipment of some 900 tons had been made to New York. It was estimated that shipments of 1,500 tons a month could probably be made, if vessels were available. A wharf had been built in deep water near the mine. Beyond that, nothing definite can now be stated regarding the development of the mine.

Several manganese deposits on the Atlantic coast of the Republic of Panama are stated [107] to have been opened up during 1916, ore to the value of about £68,500 being shipped to the United States. Further expansion of the industry is regarded as probable, other claims having been located throughout the country.

COSTA RICA.—Only one manganese mine appears to be in operation in Costa Rica, although other claims are said to have been selected. The mine is situated at Playarreal, in the Province of Guanacaste, and the ore is stated to average 55 per cent. metallic manganese (80 to 83 per cent. manganese dioxide). Shipments began in May, 1916, the output being about 300 tons a month. It was expected that an equipment

with a capacity of 3,000 to 5,000 tons a month would be completed by July 1st, 1917. The port of shipment is about 2 miles south of Braxilito, considerably north of the Pacific port of Punta Arenas [108].

CUBA.—The manganese industry of Cuba commenced some twenty years ago. There are three principal groups of deposits: the Cristo and the Ponupo, worked by Aguilera and Company, and the Cauto, worked by the Cauto Mining Company, a Rogers-Brown (United States) interest at San Nicolas, north of Santiago, Province of Oriente. The Ponupo, the largest of these groups, is said [109] to have produced up to the present about 2,000,000 tons of ore (probably for the most part manganiferous iron-ore) and to be still producing about 3,000 tons per month of a fair grade of "furnace ore" averaging about 43 per cent. of metallic manganese.<sup>1</sup> According to the same authority, the Cristo group is producing a small amount of ore that runs about 46 per cent. of manganese. The present production is about 4,000 tons monthly. The Cauto group is said to be mining about 2,000 tons of ore per month, containing [110] from 43 to 47 per cent. of manganese, 9 per cent. of silica, 2 per cent. of iron, and 0.05 per cent. of phosphorus, small lots (classed as "dioxide") being selected for shipment which contain from 85 to 87 per cent. of manganese dioxide.

Deposits on the south coast, in the San Maestro range, extend over a distance of 100 miles, and there were 88 mines in the province of Santiago de Cuba in 1907.

The manganese industry in Cuba has been hampered by lack of labour and inadequate facilities for land and sea transport. Practically all the ore produced in recent years has been shipped to Baltimore, United States, where the demand for "furnace ore" is still strong. There is a prospect of a considerable revival in the industry, which has been appreciably helped by the European war. The Commerce Report already referred to gives the declared exports of

<sup>1</sup> *U.S. Comm. Rept.*, March 25, 1918, gives production of the Ponupo group at that date as about 5,000 tons of ore per month, averaging from 38 to 40 per cent. manganese, and rather low in silica and iron.



"manganese-ore" from the Santiago Consular district to the United States in 1915 as 5,144 tons, value £18,187. In 1916, the United States received from Cuba, 30,563 tons, and, in 1917, 44,571 tons, according to *The Mineral Industry*, 1917.

None of the ore is treated at the mines, except by washing for removal of dirt. The "furnace ore" is shipped in bulk and the "dioxide" in sacks.

Large undeveloped deposits are said still to remain awaiting attention, and the outlook, if the demand and good prices continue, is considered to be quite favourable.

HAYTI.—There are said to be extensive deposits of manganese-ore in Coteaux, province of Cayes, conveniently situated for shipment. A concession for the working of these deposits was granted about 1905, but no production of any importance appears to have been made up to the present.

BRAZIL.—Manganese ore was discovered in the State of Minas Geraes in 1888, and fully 95 per cent. of the total Brazilian production has come from the Miguel-Burnier and Lafayette (or Queluz) districts of that State, the Wigg mine in the former and the Morro da Mina mine in the latter district having been the principal producers. The Miguel-Burnier district was the first to be developed, and for some years was the more important producer; but the highly successful development of the Morro da Mina mine, which became a producer in 1902, has caused the Lafayette district to assume the leading position. Manganese-ore has also been found in the States of Bahia and Matto Grosso, but the deposits in the latter State have not yet been mined, owing to their distance from the coast and prohibitive cost of transport.

The exports of manganese ore from the beginning of production in 1894 to the end of 1913 amounted to 2,579,805 long tons[III], the highest tonnage in any one year of that period being 249,954 tons, in 1910. The following statistics of exports for the years 1913-16 are as compiled from various sources. (See Diagram 7, p. 104):

(Long Tons.)

Exported to	1913.	1914.	1915.	1916.
United States <sup>1</sup> . . . .	70,200	113,924	262,584	495,179
Great Britain <sup>1</sup> . . . .	18,792	46,494	14,515	—
Germany <sup>2</sup> . . . . .	5,000	—	—	—
Belgium <sup>2</sup> . . . . .	11,600	10,400	—	—
France <sup>2</sup> . . . . .	7,098	11,200	—	—
Other Countries (by deduction) .	7,640	1,338	6,933	—
Total <sup>2</sup> . . . . .	120,330	180,680	284,032	495,179

<sup>1</sup> Official figures of actual receipts.

<sup>2</sup> *U.S. Comm. Repts.* (The French tonnage for 1913 is as given in French Customs statistics.) E. C. Harder (*loc. cit.*) gives the total tonnage exported in 1913 as 180,738 long tons.

With the exception of a small quantity produced in the State of Bahia, the Brazilian output of manganese-ore has come from the State of Minas Geraes.

The great increase in the exports of Brazilian manganese ore to the United States has, of course, been due to the cutting-off of Russian and the serious shortage of Indian supplies owing to the war. In 1916, the United States obtained 80 per cent., and in 1917 83·2 per cent., of its manganese-ore requirements from Brazil. The value of the Brazilian output in 1916 was approximately £1,495,800, or nearly £3 per ton, at Rio de Janeiro [112]. The exports of manganese-ore from Brazil during 1917 amounted to 524,434 tons.<sup>1</sup> Formerly all Brazilian manganese ore was shipped from Rio de Janeiro; since the beginning of 1917, however, extraction of manganese-ore has been proceeding in the State of Bahia, where several American companies have acquired interests, and the exports from the port of Bahia amounted during that year to 32,860 tons [113].

The Morro da Mina mine is now not only the most important in the State of Minas Geraes, but, according to F. L. Garrison [114], probably the largest manganese mine in the world. It is owned and worked by Brazilians, the next largest mine, the Cocuruto, being controlled by Belgian interests.

<sup>1</sup> The actual receipts in the United States during the year from Brazil amounted to only 512,517 tons, according to *The Mineral Industry*, 1917, p. 418.

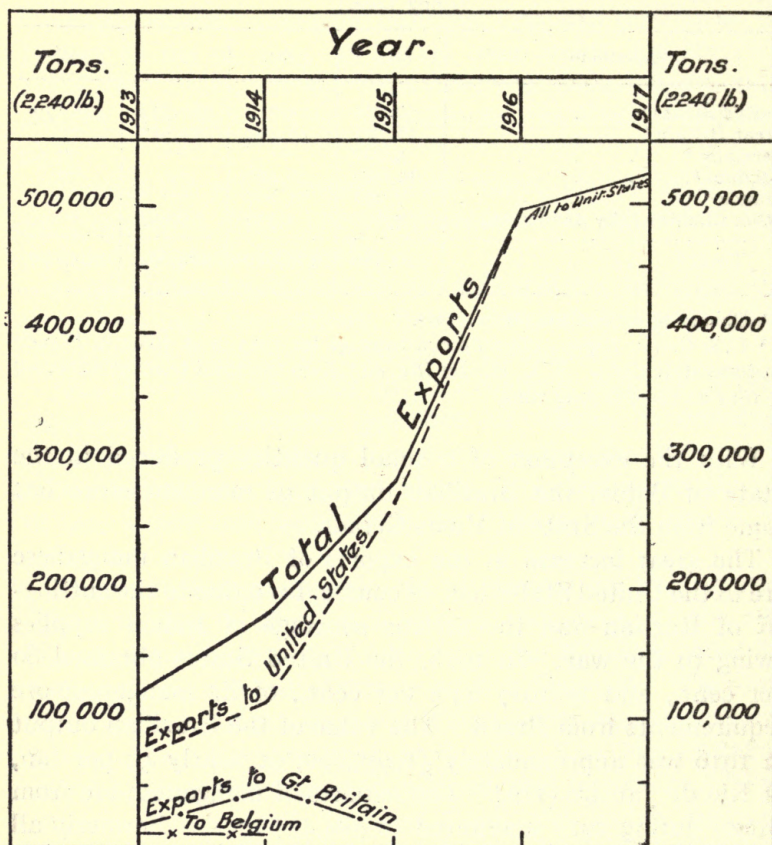


DIAGRAM 7.—EXPORTS OF MANGANESE ORE FROM BRAZIL. TOTAL AND TO PRINCIPAL COUNTRIES (1913-1917)

*The Minas Geraes Deposits.*—The ores of Minas Geraes have been separated into two classes [III]:

- (1) Those occurring in a complex of granite, gneiss and crystalline schist;
- (2) Those occurring in overlying metamorphosed sediments, with which the important Brazilian iron ores are also associated.

1. *The Crystalline-complex Ores.*—These are large irregular bodies of manganese dioxide, enclosed in, or bounded by,



gneiss, granite or crystalline schist. Individual masses may be several hundred yards in the larger diameter. While irregular in shape, they are usually somewhat elongated, suggesting lenses. They occur scattered through the crystalline complex without any apparent regularity, but most of them appear to have either gneiss or crystalline schist on one or both bounding walls. The manganese oxide composing these lenses is usually amorphous, occurring mainly as psilomelane and wad, although pyrolusite is also found. It is considered that all the manganese-oxide deposits in the areas of the crystalline complex are surface-oxidation products of manganese silicate and carbonate rock. Most of the ore is hard; but soft material, mainly wad and pyrolusite, also occurs in abundance irregularly intermixed with the hard ore.

2. *The Sedimentary Ores.*—These occur as definite beds associated with the iron formation. The principal bed, on which the Wigg mine is situated, is from 2 to 3 miles in length, with a maximum thickness of over 6 feet. Its strike and dip are parallel with that of the enclosing sediments, showing that it was laid down as a sedimentary deposit. At the Wigg mine the ore bed is bounded on one side by soft siliceous iron-formation, with a contact zone of mixed soft crystalline hæmatite and manganese oxide, and on the other side by a ferruginous schist associated with the iron formation. The dip is generally steep.

At the Rodeio mine, east of Miguel-Burnier, the manganese-ore bed is of smaller longitudinal extent, but of greater thickness than at the Wigg mine, and shows less definitely its relation to the enclosing rocks.

The manganese-ores associated with the sedimentary rocks consist of finely crystalline and amorphous manganese oxides, probably a mixture of pyrolusite and psilomelane; and these ores are of somewhat higher grade than those occurring in the crystalline complex.

E. C. Harder quotes the following as typical analyses of ore from mines in the State of Minas Geraes :

	Lafayette District.		Miguel-Burnier District. Wigg Mine.	
	Piquery Mine.	São Gonzalo Mine.	Average.	Cargo.
	Per cent.	Per cent.	Per cent.	Per cent.
Mn . . .	49.00-51.00	50.00-54.00	50.00-54.00	55.14-55.02
SiO <sub>2</sub> . . .	5.00- 7.00	1.00- 2.00	1.00- 2.00	0.53- 1.25
P . . .	0.08- 0.10	0.12- 0.15	0.01- 0.03	0.03- 0.021
Moisture . .	3.00- 5.00	3.00- 5.00	15.00-20.00	4.95- 4.74

J. T. Singewald, Jr., and B. L. Miller [115] contrast the modes of occurrence of the deposits in the Miguel-Burnier and Lafayette districts. The deposits of the former district extend as a narrow belt about 10 miles in length, parallel with the Ouro Preto branch of the Brazilian Central Railroad, and lie at the southern edge of the great iron-ore region of central Minas Geraes. The ore bodies occur as lenses or beds intercalated in a series of sedimentary strata showing a rapid succession of itabirite schist, calcareous schist and limestone. Stratigraphically, they are found in the upper part of the Itabira iron-formation and in the lower part of the overlying Piraçicaba schist, formations probably of Algonkian age. The ores are very high-grade manganese oxides, chiefly a mixture of psilomelane and pyrolusite, averaging 50 per cent. manganese, 1 per cent. silica, and 0.03 to 0.05 per cent. phosphorus. It is mentioned, as the great drawback of the district, that the beds are steeply dipping and narrow, rarely over 6 feet in width, so that expensive underground mining must be resorted to, and the individual deposits are relatively small. As to the origin of the ores, they quote two views which have been advanced: (1) that by H. K. Scott [116], who holds that, whatever may have been the original state of the manganese ore bed, there can be no doubt that in its present condition, and down to the level to which it has been worked, it is a residual deposit from which the other elements have been leached out; and (2) that by E. C. Harder [117], who regards the source of the manganese as doubtful, but thinks it may very well have been derived from deposits of manganese ore in the crystalline complex, such as now occur to the south near Lafayette. Decomposition of such deposits may have yielded a large amount of residual man-

ganese oxide, which was transported and deposited as beds or lenses in the sedimentary series. Their origin would, thus, be very similar to that of the iron-ores with which they are closely associated. The view taken by Singewald and Miller is that, while one cannot positively state that the ores were not laid down in the form of manganese oxides as integral parts of a sedimentary series, their relations to the associated limestones are such as to make their interpretation as residual products of decomposition and replacement of manganiferous limestone the more probable explanation of their origin.

As to the Lafayette district (the railway station of that name being about 20 miles south of Burnier) they remark that the geology differs markedly from that of the Miguel-Burnier. It lies to the south of the area underlain by the great iron-bearing series, and its ores are found in the basement complex of supposed Archæan age which underlies a large part of the State of Minas Geraes. The rocks making up this complex are chiefly granite and gneiss, with which are associated amphibolite, and micaceous and quartzose schists. There are also small intrusions of diorite and gabbro, mostly in the form of dykes. The granite seems to be intrusive into the gneiss and schist, but the relations between the schist and gneiss are not clear. The manganese deposits occur as elongated masses of more or less lenticular shape within the rocks of the basement complex, and represent residual products of decomposition of an original manganiferous rock made up of manganese carbonate and silicates. The immediate wall-rock of the deposits has likewise undergone decomposition, in many places being nothing more than a clay in which the original rock texture is poorly preserved. In most cases, however, it seems to have been either gneiss or schist.

The Morro da Mina mine is located on a hill 2 or 3 miles north of the town of Queluz, which is situated about 3,600 feet above sea-level and rises to a height of about 650 feet above the surrounding country. The ore bodies occur at the top and on the flanks of the hill as a series of more or less overlapping lenses extending in a direction N. 35° W., with a vertical dip and a pitch of 45° to the south-east. Of the ore bodies developed, the four largest have maximum dimen-



sions of 200 by 30 metres, 420 by 120 metres, 140 by 70 metres, and 100 by 20 metres, respectively, and, at the date of the paper by Singewald and Miller, the first two of these had been cut by a development adit 130 metres below the summit of the hill, indicating that the ores extend at least to that depth. Since it became an important producer in 1902, the mine has yielded a total considerably exceeding 1,000,000 tons, its production in 1915 being about 200,000 tons. Development work is said to have proved an ore reserve of 10,000,000 tons. In addition to the ores *in situ*, a large part of the hillside below the ore outcrops is covered with rubble ore derived from them, and in recent years about one-third of the output has come from workings in this rubble.

The ore consists for the most part of psilomelane, which occurs most commonly in a more or less drusy, massive form. Mammillary, botryoidal and concretionary forms are abundant. Associated with the psilomelane is a considerable amount of manganite and pyrolusite, which occur for the most part as cavity linings and fillings in the psilomelane.

The average composition of Morro da Mina ore, as shipped, is stated by the same authorities to be as follows:

	Per cent.
Water at 100° C. . . . .	2.50
Volatile . . . . .	12.40, chiefly oxygen.
Insol. Residue . . . . .	3.46
Fe <sub>2</sub> O <sub>3</sub> — Al <sub>2</sub> O <sub>3</sub> . . . . .	8.75, alumina about twice ferric content.
Silica (SiO <sub>2</sub> ) . . . . .	1.76
Phosphorus (P) . . . . .	0.069
Sulphur (S) . . . . .	absent
Manganese (Mn) . . . . .	50.47

The ore is mined for the most part in open cuts, the ore body being stripped of such overburden as it may carry.

*The Bahia Deposits.*—These occur about 16 miles west of Nazareth, a town on tide-water about 30 miles west of the city of Bahia. Ore has been shipped from three mines in this district. It is mainly psilomelane, occurring as lumps

and large masses in clay or soft earth. Some masses are botryoidal, but most are angular, usually ranging from mere particles up to a foot or two in diameter, those shipped having about the size of a fist. The average analysis of ore from the principal mine, the Pedras Pretas, is as follows: Manganese, 43 to 49; silica, 3 to 4; phosphorus, 0.016; moisture, 2 to 3 per cent. According to F. L. Garrison [118], the manganese-ore shipped from the State of Bahia seldom exceeds 4 per cent. in silica, 5 per cent. in iron, and 0.017 per cent. in phosphorus.

According to *The Mineral Industry* [119], Brazilian manganese-ore averages 50 to 53 per cent. manganese; 3 to 3.5 per cent. iron; and 0.03 per cent. phosphorus.

The development of the Brazilian manganese ore industry has been retarded by the distance of the more important mines from the nearest port, and the consequent heavy railway and other charges. With low rates of exchange, the Brazilian ores could compete on equal terms with those of India and Russia on the London market in pre-war times, but with high rates they were at a considerable disadvantage.

The important factor of railroad transportation to the seaport has been discussed by Kirby Thomas [120]. The manganese ore deposits of Minas Geraes lie in the southern part of that State, from 300 to 400 miles north of Rio de Janeiro, and are reached by the Brazilian Central Railroad. This railroad is owned by the Government, and is stated by Thomas to be inefficiently managed and of faulty construction. New equipment, recently installed, enabled the railroad to bring down 500,000 tons of ore, a distance of 350 miles, to the port of Rio de Janeiro during the year 1916; and it is considered that with better management 150,000 to 200,000 tons more could be transported annually.

Another factor affecting the transport of the ore consists in the limited and expensive arrangements for loading at the harbour in Rio, which has no facilities for loading bulk ores, while the transport of the material from shore to ship is under control of a hindering concession. The port conditions are such that it is necessary to unload the ore from the railroad cars on to lighters, transport it to islands in the harbour,

and from there transport it to lighters or ships. A plan to construct a dock at a harbour west of Rio has been considered, but has not materialized, chiefly owing to the failure of the leading interest to co-operate, and partly to the considerable expenditure involved.

It was reported recently [121] that an export tax of 8 per cent. on manganese-ores was under discussion by the State authorities in Minas Geraes.

CHILE.—This country was formerly a considerable producer of manganese-ore, and is known to contain important deposits of both rich and medium-grade ores, which are said to be by no means exhausted. The competition of Indian ore resulted in the collapse of the industry, and there has been practically no production since 1905. It is considered certain, however, that the mines will be re-opened. The development of the Chilean iron-ores is now proceeding actively, and this, together with the opening of the Panama Canal, may revive the manganese industry. The total exports of manganese ore from Chile between 1885 and 1905 amounted to 549,716 tons. Omitting the year 1885, when the industry was in its infancy, and the years 1904-5, when it was moribund, the average annual export was about 30,000 tons.

No adequate description of the Chilean manganese ore deposits has appeared until quite recently. According to E. C. Harder [122], the ores may be classed as follows, according to their geological occurrence :

- (1) Interbedded with jasper and chert in a limestone-chert formation.
- (2) Interbedded with red sandstone, shale and limestone, which in turn are interlayered with massive volcanic flows.
- (3) Veins in volcanic flows.

The sediments and volcanic rocks with which the ores are associated are of Mesozoic age.

To *type (1)* belong the ores of the Carrizal District, which is about 350 miles north of Valparaiso. Here the manganese ore occurs in a belt several miles in length, in from one to four parallel beds, varying up to 4 or 5 feet in thickness,



separated by a few feet of chert or jasper. The ore in the northern part of the belt is dense, hard, black psilomelane with conchoidal fracture, and usually contains much silica in the form of chert. In the southern part, the ore is hard, bluish-black braunite, with some psilomelane and an admixture of soft black oxide. The manganese mines occur along a branch of the railway from the port of Carrizal, distant about 50 miles.

To *type (2)* belong the ores of Las Cañas, La Liga, Arrayan and Corral Quemada, where they occur in from one to three parallel beds, usually averaging where mined from  $1\frac{1}{2}$  to 3 feet in thickness, and separated by only a few feet. In most places the ore beds consist of pure, granular to finely crystalline, bluish-grey or bluish-black pyrolusite, generally compact but soft.

To *type (3)* belong the ores of Aculeo and Los Chorros, as to which no useful information is available.

Most of the manganese ore exported from Chile has come from the Carrizal and Corral Quemada districts, but a considerable quantity has been shipped from Las Cañas and La Liga.

The following are analyses of manganese ore from the more important districts:

	Carrizal District.		Province of Coquimbo.			
	Coquimbana.	Huachuquina.	Mina Alta, Las Cañas.	Mina Potosí, Las Cañas.	Mina Estrella, La Liga.	Elsie Cut, Corral Quemada.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Mn . . . .	45.82	37.08	40.31	52.85	49.54	50.00
Fe . . . .	2.74	3.21	3.38	1.09	1.29	0.78
SiO <sub>2</sub> . . . .	5.42	11.97	11.20	7.74	5.00	9.43
P . . . .	0.093	0.116	0.022	0.007	0.010	0.013
H <sub>2</sub> O (combined) .	3.78	3.48	1.15	0.90	1.00	1.18

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